The Drinched Book

ON

CIVIL ENGINEERING.

SANITARY ENGINEERING.

PART II—SEWERAGE AND DRAINAGE WORKS.

BY

C. E. V. GOUMENT, C.S.I., M.I.C.E.,

Late Chief Engineer and Secretary to Government in the Public Works Department, United Provinces, India.

(Reprint).

ROORKEE:

PRINTED AT THE PHOTO.-MECHL. AND LITHO. DEPARTMENT THOMASON COL.

1926.

On sale at the Book Depot, Thomason College, Roorkee.

PREFACE.

This Manual has been prepared on the same lines as that on Water Supply which forms Part I of Sanitary Engineering. The first principles of the subject have been explained as simply and briefly as possible, leaving the student to equip himself later, if necessary, with detailed information on any particular branch by consulting more advanced books and professional papers, many of which have been suggested for reference.

In preparing this Manual, the author has availed himself freely of information contained in the numerous books, reports, and professional papers which have recently been published on this subject, but he is chiefly indebted to those noted below :—

(1) Minutes of Proceedings of the Institution of Civil Engineers.

(2) Reports of the Royal Commission on Sewage disposal, 1902 to 1912.

(3) Simple Methods of testing Sewage effluents, by G. Thudichum, F.I.C.

(4) Oriental Drainage, by C. C. James.

(5) Sanitary Engineering with respect to water-supply and sewage disposal, by Vernon Harcourt. (1908).

(6) Sanitary Engineering by Colonel Moore, R.E.

(7) The Purification of Sewage by S. Barwise, M D., B.Sc.

C. E. V. G.

July 1914.

CONTENTS.

CHAPTER I.

INTRODUCTION.

	Para.
Ancient works	1
Conditions necessary for good health	2
Conditions peculiar to India	3
Definition of "sewers" and "drains" ...	4

CHAPTER II.

SYSTEMS OF COLLECTION AND REMOVAL OF REFUSE

Present state of sanitation in India	5
Different systems of removal	6
Hand removal	7, 8
Gravitation system	9
Gravitation and pumping	10

CHAPTER III.

SEWERS AND UNDERGROUND DRAINS.

Alignment of sewers	11
Separation of rainfall from sewage	12
Materials used in construction	13
Various forms of sewers...	14
Fall and velocity	15
Flushing	16 to 20
Catch pits and gullies	21
Manholes	22
Construction	23 to 25
Clearing obstructions	26
Ventilation	27 to 30
Outfalls	31
Sub-soil drainage	32
Storm overflows	33

CHAPTER IV.

Surface drains.

	Para.
Alignment	34
Slopes	35
Sections	36 to 39
Provision for rain water	40
Flushing and cleaning	42
Junctions	43
Road crossings	44
Details of drainage projects	46

CHAPTER V.

House drainage.

Water closets	47, 48
Flushing arrangements	49
Soil pipes	50
Urinals	51
Slop sinks	52
Baths	53
Lavatories	54
Kitchen sinks	55
House drains	56, 57
Fall of house drains	58
Test of drains	59
Construction	60
Indian adaptations	61
Connection with sewers...	62
Privies and water closets for Indians	63, 64

CHAPTER VI.

Sewage lifts.

Shore's hydro-pneumatic system	66 to 68
Liernur vacuum system	69, 70
Hydraulic system	71, 72
Automatic sewage lift	73 to 75
Electrical system	76

PARA.

CHAPTER VII.
PUBLIC CONVENIENCES.

Dry pattern latrines	78
Water-flushed latrines	79
Trough latrines	80
Urinals	81
Underground conveniences	82

CHAPTER VIII.
SEWAGE DISPOSAL.

Selection of a site for an outfall	83
Classification of sewage	84, 85
Electrolysis...	86
Disposal where free outfall is not feasible	87 to 91
Land irrigation	92 to 99
Intermittent sand filtration	100
Septic tanks	101, 102
Upwards filtration	103
Contact beds	104
Slate beds	105
Continuous trickling filters	106
Tests of purification	107 to 116
General conclusions	117, 118

APPENDIX A.

PAGE.

Extracts from "Directions for the preparation of a drainage project" issued by the Sanitary Engineer to the Government of the United Provinces and Oudh	i—iv

APPENDIX B.

Extract from Dr. Fowler's report on the treatment of sullage in the United Provinces	v—vii

APPENDIX C

Extract from a selected paper in volume 135 of the Proceedings Inst. C. E. on the Karachi sewage works ...	viii—ix

APPENDIX D.

Note on sub-soil drainage ...	x—xii

PART II. —SEWERAGE AND DRAINAGE WORKS.

CHAPTER I.

INTRODUCTION.

1. **Ancient works.**—Sewering and draining in a crude manner are probably as old as the civilization which brought individuals and communities together in towns. Examples of old sewers exist in India and China. Rome and other cities of Italy were partially sewered and many of the important public buildings were drained. But there is no evidence to show that entire town sites, including streets and houses, were at any period fully and systematically sewered as European towns now are. The large underground drains discovered in ancient cities such as the *Cloaca-Maxima* of Rome, were really valley-line culverts and could hardly be called main sewers in the present sense of the term. A system of sewers and drains constructed on scientific principles to transmit continually and regularly surface drainage and excreta from the site of a town to a distant outfall may therefore be fairly considered a product of modern civilization.

2. **Conditions necessary for good health.**—If the human body is to enjoy health and vigour it is essential that all matter eliminated from the animal system and all animal and vegetable refuse should be removed from the vicinity of inhabited buildings as speedily as possible before decay begins, as, in the early stages of putrefaction, the matters evolved are very injurious to health and dangerous to life. This is especially the case wherever human beings gather together in large numbers, as in towns and villages. As the size of a community increases, so does the difficulty in getting rid of the refuse, more especially the liquid refuse which contains foul matter in suspension and solution. Dry refuse may be collected in receptacles and carted away, but liquid matter requires more elaborate arrangements.

3. **Conditions peculiar to India.**—The prejudices and habits of the people of India are opposed in many respects to the European system of drainage, and this adds many difficulties to the satisfactory solution of drainage problems in this country. The habit which is common in the East of scouring metal domestic utensils with ashes, sand or road detritus increases the tendency to blockage in pipes and sewers and gully traps, and the use by natives of leaves instead of plates, which are

thrown after use into the sinks or drains, also tends to produce the same effect. The climatic conditions of a tropical country introduce other factors which require special consideration. The temperature in sewers being generally high, putrefaction takes place rapidly and gradients of sewers which are considered in Europe to give sufficient velocity for the removal of solids are found to be insufficient in India. The high temperature, moreover, causes an excessive formation of gas in sewers and special consideration has to be given to the subject of ventilation. Another serious difficulty in the way of following strictly European methods in Indian drainage schemes is the comparatively slender resources of the municipalities. The funds available are often insufficient to admit of all the streets of a town being sewered and all houses being connected with the general system. Branch drains serving houses and narrow side streets are, as a rule, made open surface drains in this country because they are cheaper and because they can be easily cleaned and generate no sewage gas. The intercepting drains and main conduits in the valley lines are usually underground. Water closets of the European pattern can only be used in houses on streets which have underground sewers. In the minor streets served by open surface drains, only the sullage from kitchens and lavatories of houses is admitted into the drains, the night soil being removed daily by conservancy carts to sewage farms or trenching grounds outside the town.

4. **Definition of "sewers" and drains**.—Underground street conduits for conveyance of liquid foul refuse are generally termed "sewers," while surface channels carrying rain water or sullage from houses from which night-soil has been excluded are called "drains." The pipes and channels conveying liquid waste and refuse from houses are also called "drains."

CHAPTER II.

SYSTEMS OF COLLECTION AND REMOVAL OF SOLID AND LIQUID REFUSE.

5. **Present state of sanitation in undrained towns in India.**—Until quite recently there was practically no regular sanitation in the towns of India owing to the absence of a sufficient water supply, the indifference of the people, and the want of funds. Open side drains of rectangular section, made without any regard to gradients or volume to be dealt with and flushed occasionally by showers of rain, formed the only drainage system of a town, if one existed at all. The outfalls were generally at the edge of the town in unlined natural drainage channels of insufficient slope, in which the small quantity of sewage that reached them collected in putrid pools and poisoned the air for a considerable distance around. The recent growth of education and prosperity has created a demand for better sanitary conditions, and the severe lesson learnt from successive epidemics of plague, cholera, and other filth diseases has opened the eyes of the people and the authorities to the advantages of good sanitation. Most of the large towns of India have now either laid down, or are preparing to lay down, some modern system of sewerage and drainage suitable to the locality.

6. **Different systems of removal of refuse.**—The systems of removal of refuse may conveniently be classed under three heads :—

1. Hand removal.
2. By gravitation in sewers.
3. By gravitation and pumping.

7. **Hand removal.**—The system of hand removal, or the "Conservancy system" as it is commonly called, was no doubt the earliest attempt towards sanitation. In places where no modern sewerage system exists, cess pools are necessary for the collection of sullage which is periodically removed to the nearest natural drainage channel outside the town or applied to land, the night-soil being collected separately in latrine pails and taken once or twice a day to a convenient spot outside the town where it is buried in trenches. In most Indian towns and villages this system still exists. In some places which can afford it, Cawnpore for instance, a slight advance has been made, and sewers have been laid in the main valley lines into which the sullage and night-soil are discharged from

conservancy carts. These sewers merely reduce the lead of the refuse carried in carts and act as outfalls, but do not obviate entirely the necessity for hand removal. Calcutta, Bombay and Madras are the only three towns in India, as far as the Author is aware, which have undertaken an underground sewerage system on an extensive scale.

The system of hand removal is undoubtedly insanitary for several reasons. The collection of sullage and faeces for several hours in the close vicinity of dwelling is distinctly objectionable; the passage of sullage and night-soil carts through closely inhabited streets is most offensive; the emptying of these carts at various dépôts in or near the town liberates a large amount of offensive gases which must be injurious to health. It is not every town, however, that can afford to have a more up-to-date system, and such attempts are better than leaving refuse of every description to putrify in the open air in streets and houses.

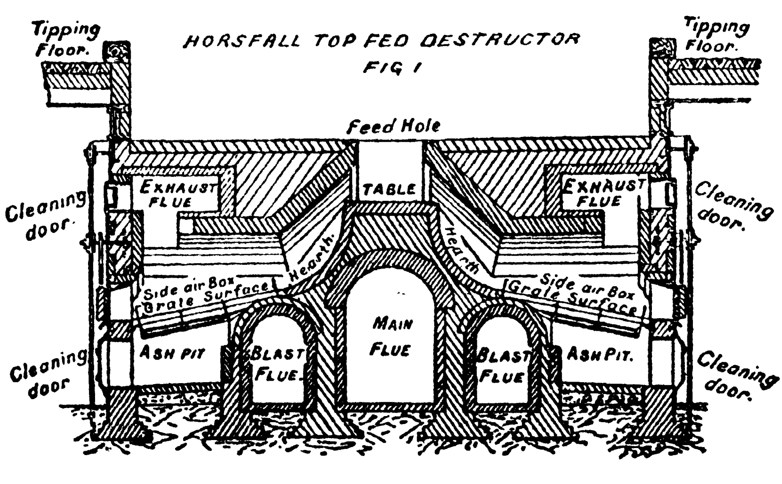
8. In addition to the sullage and night-soil there is a certain amount of dry solid refuse to be got rid of, such as paring of vegetables and fruit, cinders, ashes, waste paper, dry leaves and the like. In villages and small towns, such refuse is carried out and collected in a heap which is either burnt periodically or used for filling up hollows. In large towns where great quantities of such refuse are collected, refuse destructors may be employed with advantage. In the earlier refuse destructors, the cumbustion was effected slowly with natural draught at a temperature which was not sufficient to consume thoroughly all the putrescible portions of the refuse and the chimneys emitted noxious fumes which caused a serious nuisance in the vicinity. The present practice is to drive air with fans by a forced draught into the furnace or, where the refuse has a sufficient proportion of combustible materials, to keep up a high temperature by jets of steam which are converted into water gas by decomposition when exposed to great heat. All the refuse is thus completely consumed and the gases passing up the chimney are inoffensive. Roughly speaking, two forms of destructors are in use and there are two methods of feeding the fires. In one form, the cells are fed from the top, the refuse being tipped on to a floor above the furnaces. From this floor, it is put through a central hole on to a table from which it is pushed as required into the cells. See *Fig.* 1. The cells may be placed back to back as shown in the figure if a large number are required and economy of space is essential, or, they may be placed side by side in a single row if this arrangement is more convenient. In the other form, the cells are in a single row and the feeding is generally effected by

raising it from an adjoining floor by shovels and spreading it over the cells as required. See *Fig.* 2. The former is the Horsfall system and the latter the Meldrum. The top fed destructor reduces the labour of charging the furnaces to some extent, but it has the disadvantage of heating the refuse spread on the floor above the furnace, producing dust and offensive smells, and of feeding the cells with heaps of refuse which is not uniformly distributed over the grates. The platform, moreover, to which the refuse has to be raised, is 15 to 20 feet above the ground and consequently necessitates a long approach road for the carts on which it is conveyed to the destructor. Devices have recently been introduced, notably by the Horsfall Company, to feed the furnaces automatically from the carts by mechanical contrivances and so dispense with the necessity of handling the refuse as far as possible, which is obviously a great improvement from a sanitary point of view, though somewhat expensive.

Though the primary object of refuse destructors is to consume the refuse, they are sometimes so designed as to supply heat to steam boilers for electric lighting and other purposes. Students are referred to the following publications for further information on the subject of refuse destructors :—

"Refuse Disposal and Power Production," by W. F. Goodrich.

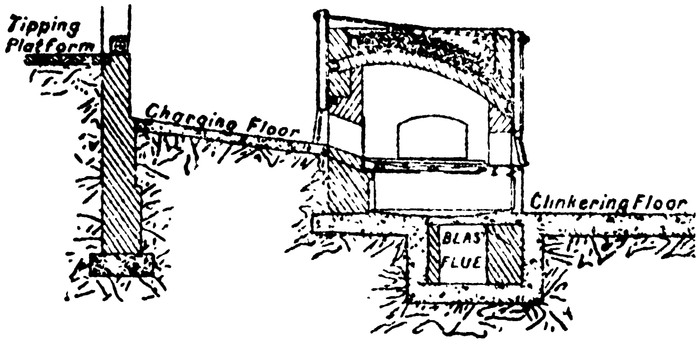
"Combined Refuse Destructor and Power Plants," by C. N. Russell.



HORSFALL TOP FED DESTRUCTOR
FIG 1

MELDRUM DESTRUCTOR

Fig. 2



9. **Gravitation in Sewers.**—There are several kinds of gravitation systems of sewerage, but they all require an ample supply of water to carry the sewage at a good velocity through the sewers to the outfall. There are two main systems—

(1) the combined system; and

(2) the separate system.

By the former all sewage and surface water, including rain water, are carried in the same sewer; by the latter, the foul water is carried in one set of drains and the surface water in another.

The combined system is not applicable generally to a country like India, where the rainfall is restricted practically to about four months of the year and is very heavy during that period. Under such conditions, it is impossible to design sewers capable of running at a self-cleansing velocity in the dry weather and large enough at the same time to deal with the surface water in the rainy season. Sewers constructed larger than necessary for sewage proper run at a low velocity in the dry weather and soon become charged with deposit, and the expense of constructing sewers large enough to carry off the maximum rainfall, as it occurs, would be prohibitive. A combination of the two systems which disposes of all the sewage and the first run off of rain water which is generally foul (varying in quantity from $\frac{1}{8}''$ to $\frac{1}{4}''$ according to local conditions) is the best for India. Much smaller sewers can be used in this system which require a smaller supply of water to keep them clean in dry weather, while the formation of sewer gas inside the sewers is reduced to a minimum. Town sites necessarily have natural surface drainage and frequently there are old drains to remove storm water. If these

drains are imperfect they should be improved and made efficient as the work of removing heavy falls of rain should not be thrown on sewers if it can possibly be avoided. It may sometimes happen in designing a scheme that a new main sewer, if constructed large enough, could be usefully and economically employed for the rapid removal of storm water from low parts of a town which cannot be drained otherwise without great expense. Such cases require special consideration and it may be justifiable under these conditions to make a sewer large enough to take ½" or even 1" rainfall per hour.

10. **Disposal by Gravitation Sewers and Pumping.**—When the town site to be drained is so flat that the sewers cannot be given a sufficient slope without getting them down to too low a level for free discharge, it becomes necessary to raise the sewage to ground level at one or more points by means of steam, compressed air, oil engines, hydraulic engines or electric pumps. It is generally necessary in such cases to divide the whole area into sections, to collect the sewage of each section by gravitation at a central point, lift the sewage at each of these points by means of power generated at a central station and force it to a common outfall.

If the whole of the sewage can be gravitated to one point on the outfall from which it has to be raised, the type of engine commonly used in installations requiring not more than 25 brake horse power is an oil or gas engine working a centrifugal pump or a three-throw vertical ram pump with externally packed plungers. For larger horse powers, steam engines are generally preferred in connection with the same class of pumps, though Diesel and semi-Diesel oil engines are also suitable if they can be placed in charge of a fully qualified Superintendent. Centrifugal pumps are simpler machines than reciprocating pumps and cheaper in first cost but their efficiency is comparatively low. Of the reciprocating variety, vertical ram pumps are more suitable for sewage than the bucket-and-plunger type as they are less affected by grit which, as has already been pointed out, exists in large quantities in Indian sewage. The valve area in a pump of the latter type is also of necessity very restricted which is a most undesirable feature where a thick liquid-like sewage has to be dealt with. With ram pumps, the valves can be so arranged as to be entirely independent of the ram and can thus be made of sufficient area.

When the flatness of the ground will not permit of all the sewage being gravitated to one point on the outfall and it is necessary to deal

with the site in sections, one or other of the following systems has to be resorted to:—

(1) Shone's Hydro-Pneumatic Ejector System.

(2) Liernur Vacuum System.

(3) Hydraulic System.

(4) Adam's Sewage Lift.

(5) Electrical system.

These systems are described in Chapter VI.

CHAPTER III.

SEWERS AND UNDERGROUND DRAINS.

11. **Alignment of sewers.**—No hard-and-fast rules can be laid down with regard to the alignment of main sewers and their branches which shall be applicable to all towns, but there are certain points which must always be kept in view in planning a sewerage scheme. The first is to observe the natural drainage lines, because all lines of sewers must, to a great extent, follow the slopes of the site, and the second is to consider where the sewage is to be finally disposed of and the lines of outfall leading to the place or places of disposal. Before a design for a drainage scheme can be taken in hand, it is necessary to have a map, on a large scale, showing clearly the levels of existing roads, drains, house floors, and all low places below the level of the streets. If such a map does not exist it must be prepared on a prismatic compass survey, as without it, it is not possible to fix the positions of the sewers required. The details required in this map are fully described in the directions contained in para. III, Appendix A.

Whether the whole of the drainage system of a town is underground or not, the sewers in the main streets or valley lines are generally made underground for two reasons, (1) to keep them as low as possible with the view to improve the gradients of the branches, and (2) to widen the useful surface of main streets for traffic by dispensing with the wide open side drains which would otherwise be necessary.

If the site is undulating and fairly high, it will be possible, in most cases, by careful observation of the levels, to get a gravitation scheme for the whole town which will carry all the sewage by one or more outfall sewers or drains to the sea, to a river, or to one or more plots of land where it can be dealt with on a sewage farm or in biological disposal works. In such cases there will be no difficulty in aligning the sewers as they will follow as a rule the valley lines of the site. If the country is very flat, or the whole of the site lies below the spot on which the disposal works must be located, it will be necessary to employ one or other of the lifts described in Chapters II and VI to raise the sewage to the level required, and the outfalls and sewers must be arranged accordingly. If

the ground is irregular and some of it lies above the outlet level and some below, the sewers should, as a rule, be so aligned along contour lines as to intercept as much of the sewage as can possibly be disposed of by gravitation to the point of outflow, leaving only the discharge from the low-lying part of the site to be dealt with on a different plan. Sewers which catch the flow from the higher parts and lead away by gravitation to the main outfall are called intercepting sewers. Sewers are invariably aligned in straight lengths between manholes and lampholes to facilitate inspection and cleaning.

12. **Separation of rainfall from sewage.**—The alignment of the sewers having been determined, the next important point to be considered is the amount of rainfall to be admitted into the underground system of sewers. In Upper India and near the coast lines, rainfall amounting to 2" per hour is not unknown, and 1½" per hour is fairly frequent in the monsoon season. The cost of sewers to carry such excessive rainfall, *as it occurs*, would be impracticable and altogether beyond the means of Municipalities. As explained in Chapter II, the sewers can only be made large enough to deal with the foul discharge from the town, and the run-off from the site, during very heavy rainfall, which is comparatively clean water, must be dealt with by making use as fully as possible of the existing natural means of surface drainage, leaving these as they are if they have hitherto been found to be efficient, or improving them where they have proved defective.

The foul discharge the sewers should take must, however, consist of a certain amount of rainfall in addition to sewage, as the rain water flowing off the streets and courtyards of houses during gentle showers, or when rain first begins to fall, is often just as impure as the fluid ordinarily conveyed by sewers. Engineers differ in opinion as to what this limit of rainfall should be, but a large majority seem to be in favour of fixing it at ¼" per hour where the auxiliary system of surface drainage is considered sufficient, and providing more, up to one inch per hour, where the underground sewers, especially in main valley lines, have chiefly to be relied upon for carrying off the discharge of heavy storms. As the actual quantity of sewage and flushing water in sewers is small as compared with a run-off of ¼" per hour from the drainage areas served and flushing is not, as a rule, carried out when rain is falling, it is usual, for simplicity of calculation, to make the sewers large enough for a total run-off of ¼" per hour including sewage, and not to take into account any losses from absorption and evaporation.

13. Materials employed for sewers.—The materials generally used in India for the construction of sewers is, for small sizes, earthenware pipes, and for large sizes, brickwork and concrete. Iron pipes are substituted for earthenware on steep slopes where velocities are excessive and in places where they are liable to fracture from settlement in soft ground, from pressure of earth at great depths below ground surface, or, if near the surface, from heavy vehicular traffic. In Europe and America, large sewers of 7 feet diameter and over are sometimes made of reinforced concrete, but as this material is comparatively very expensive in India and sewers of very large sizes are seldom required in this country, this method of construction will not be further referred to in this Manual. Students should refer to Buel and Hill's book on reinforced concrete if they require further information on the subject of reinforced concrete sewers.

Earthenware or stoneware, as it is sometimes called, is largely manufactured in Lambeth, London, and in India at Raniganj and Jubbulpore. English pipes are of course much superior in quality but their cost is very great as compared with Indian pipes, and for this reason the latter are commonly used for ordinary purposes, the former being reserved for special work where greater strength and durability are essential. The ordinary limit of size of stoneware pipes is about 18″ diameter beyond which brickwork or concrete is generally used. Concrete pipes are sometimes made in England for sewers between 18″ and 30″ diameter. They are made in moulds with granite chippings and cement, and are very hard but they have not the strength of stoneware pipes, and they are generally surrounded with 4″ of cement concrete laid *in situ.*

A good stoneware pipe should be truly straight and cylindrical, thoroughly salt-glazed, burnt free from cracks and flaws and perfectly smooth inside. When immersed in water it should not absorb more than 2 per cent. of its own dry weight after 48 hours immersion. Sound stoneware pipes will stand a bursting pressure of 30 lb. per square in., but it is hardly necessary to test them to this pressure as they generally work as ducts and are seldom or ever under high-water pressure unless laid at great depths below ground surface.

Bricks used for sewers should be specially moulded and selected for hardness, as they are liable to severe erosion from moving grit etc., especially at the inverts. The invert blocks are often made of stoneware or cement concrete to make sewers more durable. The cementing material should be selected with great care, as there are numerous examples of

sewers in England which have failed owing to the use of limes which are not fit to withstand the chemical action of the sewage. Portland cement with an admixture of sand 1—1½, makes a suitable mortar, but it is too expensive for ordinary work in India. Neat kankar lime, or a mixture of one kankar lime to one clean sand if the kankar lime is exceptionally good, is often used for sewers in Upper India, but it is always advisable to make some experiments in each case with the lime to be used before finally deciding on its adoption. Ordinary lime in contact with ammonia converts it into nitric acid which attacks and destroys the lime. The best method of testing the suitability of a lime for sewer work is to prepare the mortar in the ordinary way and immerse it for a time in a solution of ammonia and note the effect. All brick sewers should either be plastered, or deeply pointed inside with Portland cement.

Cement or lime concrete is sometimes used for sewers either by itself or in combination with brickwork. In the latter case, the outer part of the sewer is made of concrete with an internal lining of brickwork. Concrete sewers should always be plastered or rendered with strong cement mortar on the inner face and the lime used in their construction should be selected with the same care as that employed for brick sewers

14. **Various forms of sewers of brickwork or concrete.**—An egg-shaped section is usually employed for the smaller size of sewers. The advantage of this section is that it affords a much greater hydraulic mean depth for small flows than a circular section of the same area and consequently a greater velocity for the same fall with less liability for deposit to occur. On this account it is specially suitable for very variable flows, and particularly so where the flow is at times very small. The old sewers, as exemplified by the Cloaca Maxima in Rome, were flat-bottomed with vertical side walls and a semi-circular arch at the top, and this section was adopted even in the early part of the last century, the design originating most probably in the necessity for covering over streams as towns enlarged and utilizing them eventually as sewers. In the ordinary form of egg-shaped or ovoid sewer, the vertical height is one and a half times the transverse diameter or three times the radius of the covering arch. The invert is struck from a centre on the vertical height with a radius equal to one-eighth of the transverse diameter and the sides are struck from centres in the prolongations of the transverse diameter with a radius equal to one and a third times the length of that diameter. *Figs.* 3, 4 and 5 show sections of ovoid sewers made of (1) brickwork, (2) concrete, (3) partly brickwork and partly concrete. *Fig.* 6 shows another type of ovoid sewer

used in traversing soft or treacherous ground The lower half of the sewer is well embedded in a substantial wide block of concrete.

Fig. 3.

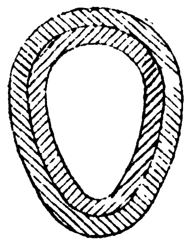


Fig. 4.

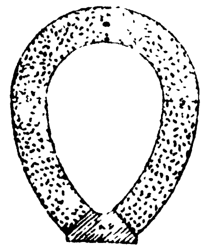


Fig. 5.

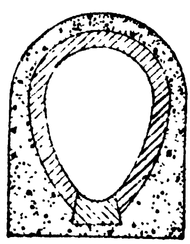
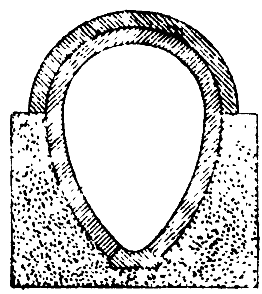


Fig. 6.



For ovoid sewers 2 feet to 3 feet transverse diameter, built with Indian bricks in solid ground not exceeding 20 feet in depth, the thickness of the sewer is usually made two bricks or one brick with an external shell of 6″ of lime concrete. For sewers 3 feet to 6 feet transverse diameter the thickness is increased by one brick or 4½″ Large sewers are usually made circular in section with two or more rings of brickwork according to the size, the nature of the ground, and the pressure of earth to which they may be exposed. For large sections the circular sewer is preferable to the ovoid as large sewers are seldom required to deal with so little sewage as to make an egg-shaped sewer of similar capacity advantageous, and circular sewers are stronger and more economical in construction.

15. **Fall and velocity in sewers and their size.**—The falls required for sewers are inversely proportional to their sizes and the ordinary minimum flow in them. A small fall causes a sluggish flow and heavy deposits, while an excessive fall produces high velocities which are apt to injure

the sewer. Experience shows that in India, where sewage is heavily charged with grit and large solid matter, the velocity during hours of ordinary daily maximum flow should be 3 feet per second or over, to get a good self-cleansing flow, but in brickwork or concrete sewers it should not exceed 5 feet per second to preserve the sewer from injury by the current.

The best available fall within safe limits should naturally be given to sewers in order to keep down their size for a given discharge, but local conditions often necessitate considerable variations. At very sharp bends the fall should be slightly increased to allow for the retardation of velocity at these points, and branch sewers should never be made less than 8″ in diameter to avoid frequent blockage. An ovoid sewer does not require as much fall as a circular of the same area owing to its larger hydraulic radius for small flows and main sewers having a large flow from a considerable area can be kept free from deposit with a smaller fall than branch sewers. Falls of 1—300 to 1—800, according to size and discharge, are *as a rule* suitable for sewers of moderate dimensions from 18″ to 54″ transverse diameter but intercepting and outfall sewers with a large considerable continuous flow may be given less falls, especially if special flushing arrangements are provided. The falls suitable for pipe drains are given in the chapter on House Drainage.

The dimensions of sewers depend upon the fall and the volume of rain water in addition to the sewage which they have to discharge. Numerous tables have been compiled giving the discharge of sewers, both circular and egg-shaped, running full and half full, for the ordinary falls and common sizes. Such tables will be found in abundance in most books on Sanitary Engineering. The formula most in favour with Engineers of the present day for calculation of velocities in brick or iron or earthenware sewers is $V = 124 \sqrt[3]{R^2} \sqrt{S}$. in which V is the velocity in feet per second, R the hydraulic radius and S the surface slope or fall divided by the length. The relative simplicity of this formula enables the velocity to be readily calculated for any form of sewer with a given fall and dispenses with the necessity of reference to tables, which do not always give the velocities for the particular cases required. This formula will be found fully discussed in a paper by W. S. Crimp, and C. E. Bruges in the Proceedings of the Institution of Civil Engineers, Vol. CXXII, page 199. The velocity having been obtained, the discharge is easily calculated from the sectional area. The tables and diagrams published by Crimp and Bruges for use in designing sewers and water mains are recommended as being very useful in designing sewerage schemes.

When the fall is so excessive that it would produce an undue velocity of flow, it should be broken at intervals by the introduction of steps or vertical falls at convenient places. Manholes should always be built where these steps occur and, if the vertical drop is considerable, a cushion of water should be provided at the bottom of the manhole to relieve the shock of the falling water.

In very flat districts where the available fall is insufficient to produce a self-cleansing velocity in the ordinary course, some assistance might be derived from special flushing arrangements at the head of each flat length. When the flatness of the site is such that it is not possible to run the sewage out by gravitation alone, one or other of the lifts described in Chapter VI must be resorted to at one or more points.

16. **Flushing arrangements.**—It depends on the fall of the drains and the flow of sewage in them whether flushing is necessary or not and, if necessary, the number and size of the flushing tanks required. It is generally advisable to fix a tank at the head of each section, and if the sewer is a very long one, flushing tanks will be required at intervals along its course, unless it is joined by a sufficient number of branches, the flushes from which are delivered simultaneously. A flush discharged at one point into a sewer tails off gradually into a shallow stream which must be augmented by another flush at a lower point if it is to be effective in removing deposits. The most suitable distance apart of flushing tanks is best determined by observation of flow in the sewers at manholes after the sewer has been brought into use These observations will also decide the size of flushing tanks required to supplement the sewage flow and produce a self-cleansing velocity to keep the sewers free from deposit. The following sizes for flushing tanks at the heads of sections will be found sufficient to begin with ; they can easily be enlarged later as required :—

9 pipe at 1—200	.. .. ..	300 gallons.
ditto 1—300	.. .. ..	400 „
12 pipe at 1—300	.. .. ..	600 „
ditto 1—400	.. .. ..	700 „
18" pipe or barrel at 1—500	.. ..	800 „
2 ft. × 3 ft. sewer	.. .. ..	1,500 „
3 ft. × 4′—6″ sewer	.. .. ..	2,500 „

17. *Plate I* shows two forms of flushing tanks : one automatic, and the other worked by hand. Automatic tanks are sometimes uncertain in their action and wasteful in their consumption of water, but for large towns they are indispensable as they save labour and do not need daily attention from the Sanitary staff. For small provincial towns the

hand-worked variety will generally be found more suitable especially if the flushes are delivered according to a time table so that each tank is discharged at or about the time when the flush from the tanks above has reached the point where it is placed. Such a time table is readily prepared by observation of the flow in manholes at certain points when flushing is in progress.

The automatic type of tank shown in *Plate I* is the Bombay pattern.* It is simple and inexpensive and thoroughly suitable for Indian towns. It consists of a large underground cistern of brickwork, masonry or concrete, covered with rough stone slabs and may be made of any size required by increasing its length, width or depth. It should be cement plastered inside to make it watertight. The flushing siphon is fixed in a chamber in the middle of the tank and the floor slopes both ways towards it. The lower end of the siphon tube dips into the water seal in a lower chamber. The tank is filled slowly by an inlet controlled by a reverse ball valve pipe, and the water rises in the tank till it reaches the lip or adjutage of the siphon tube. It then drops over carrying some air with it, and this continues until a partial vacuum is formed and siphonic action is set up which readily discharges the whole of the contents of the tank. There are many other varieties of flushing tank, but the action is practically the same in all.

The drawing of the hand-worked flushing tank in *Plate I* explains itself and needs no description. In the larger sizes, an ordinary sluice valve will probably be found more satisfactory than the chain-and-plug arrangement shown in the drawing

18. If a canal or stream is available, it may be possible in some schemes to take water from these for flushing purposes and branch pipe sewers may often be flushed conveniently from ordinary standpipes in towns which have a pipe water-supply under pressure. Where no regular water-supply is available, it will be necessary to raise the water from wells for filling flushing tanks. A portable boiler and pump might be used for this purpose by means of which many tanks could be filled in the course of the day or a pulsometer might be fixed in each well and a small portable boiler on wheels provided to work the pulsometers in turn for a short time each day. The latter method has been adopted for small towns in the United Provinces which cannot afford a more elaborate arrangement and works very satisfactorily.

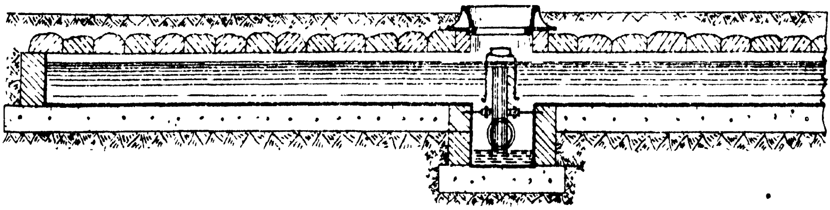
19. Flap valves, introduced at intervals, are very useful for flushing large sewers and economize the use of flushing water. These are placed on

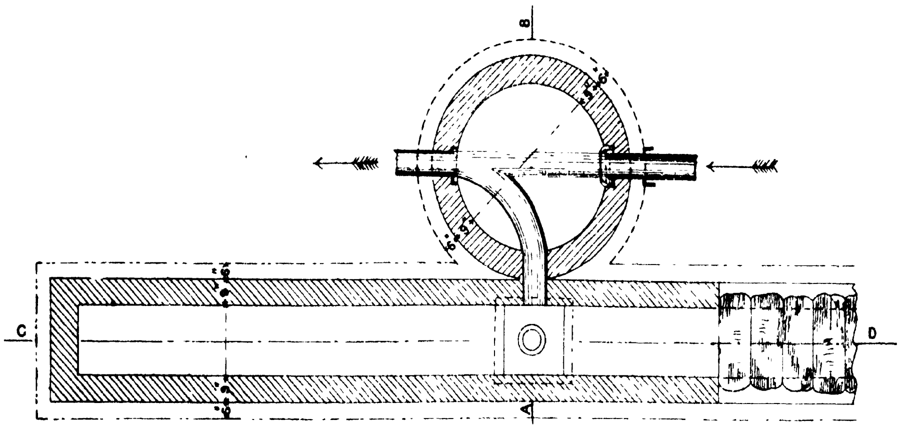
* "Oriental Drainage," by C. C. James.

PLATE I.

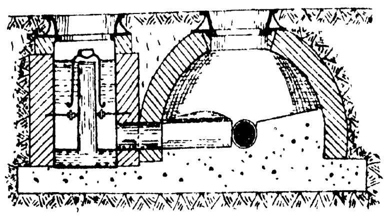
AUTOMATIC FLUSHING TANK

SECTION ON C.D.



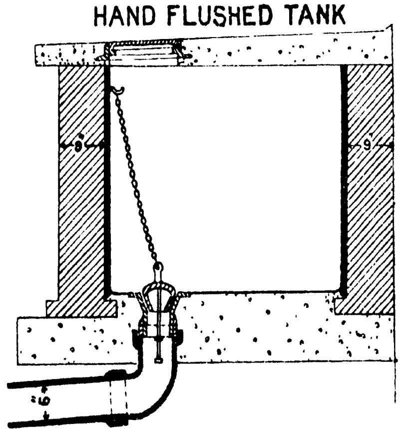


PLAN.



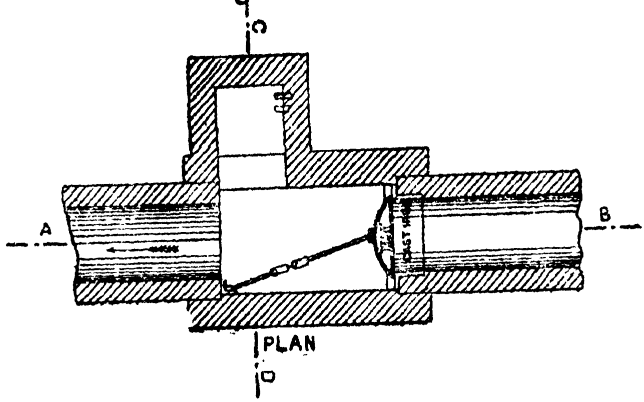
SECTION ON A.B.

HAND FLUSHED TANK



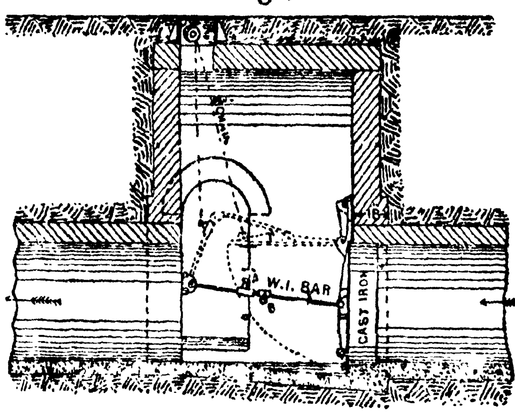
the inlet side of the sewer in a manhole; when required for use, they are securely shut down to head up the sewage on the upper length which has been previously cleared. On releasing the flap, which should be done as rapidly as possible, the whole of the pent up sewage rushes forward at a high velocity carrying before it all deposits. Large flap valves are secured by a hinged strut to keep them tightly in position when closed and to the strut is attached a chain which also lifts the flap to a horizontal position when the strut is raised. See *Figs.* 7, 8, 9.*

Fig. 7.



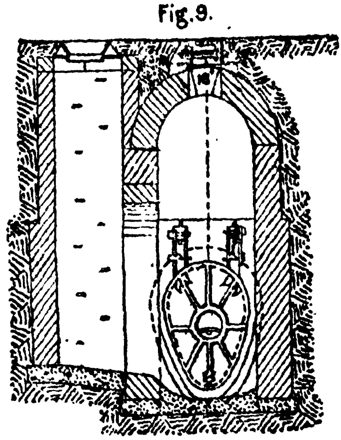
PLAN

Fig. 8.



SECTION ON A.B

Fig. 9.



SECTION ON C.D.

20. A somewhat similar method of flushing can be used for pipe sewers, but the disc valve in this case, being comparatively small is usually placed on the outlet from the manhole and no strut is necessary.

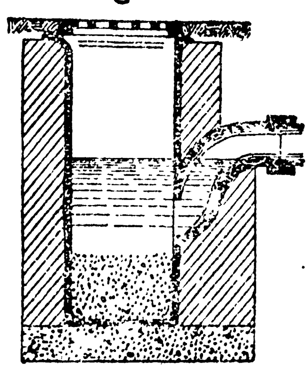
* "Oriental Drainage," by C. C. James.

Such valves, if used, should be fixed at intervals of 500 to 1,000 feet according to the gradient. Where a liberal supply of water is available a more satisfactory method of flushing sewers and pipes from manholes is to close both the inlet and outlet and fill up the manhole with clean water. On re-opening the sewer on the lower side a more thorough flush is effected with clean water instead of sewage.

21. **Catchpits and street gullies.**—Catchpits are necessary at intervals on long lines of sewers to intercept the large amount of mineral matter in the shape of ashes, sand, and road detritus which finds its way into Indian sewers through branch drains and there should be a catchpit at each junction of a surface drain with an underground sewer or drain. An example of the latter may be seen in *Fig.* 61. The former, though more elaborate, are constructed on the same lines in enlarged manholes.

Where sewers run under streets which discharge storm water into them, it is very important to catch the solid matter washed off the streets through gratings at the sides and prevent it from reaching the sewers. Gullies are therefore provided under the gratings which receive the rain water from the street and pass it into the sewer but intercept the solid matter which is removed periodically by means of iron ladles. These gullies are trapped to prevent the escape of sewer gas into the street. *Fig.* 10.

Fig. 10.



22. **Manholes.**--Manholes or inspection chambers are necessary at all junctions, steps, catchipts, and bends, and at intervals of 300 to 400 feet on straight lines so that sewers can be readily inspected and cleaned periodically. On lines with numerous bends at short intervals, lampholes may be advantageously inserted between two manholes, down which a lamp may be lowered to the sewer so that any deposit in the lengths on either

side may be observed from the manholes and located. Lampholes usually consist of vertical pipes of small diameter from the top of the sewer to the street. *Fig.* 11 shows a manhole and lamphole, and the sewer between them being cleaned by a sweeper. *Fig.* 12 shows a typical manhole at a junction.

Fig. 11.

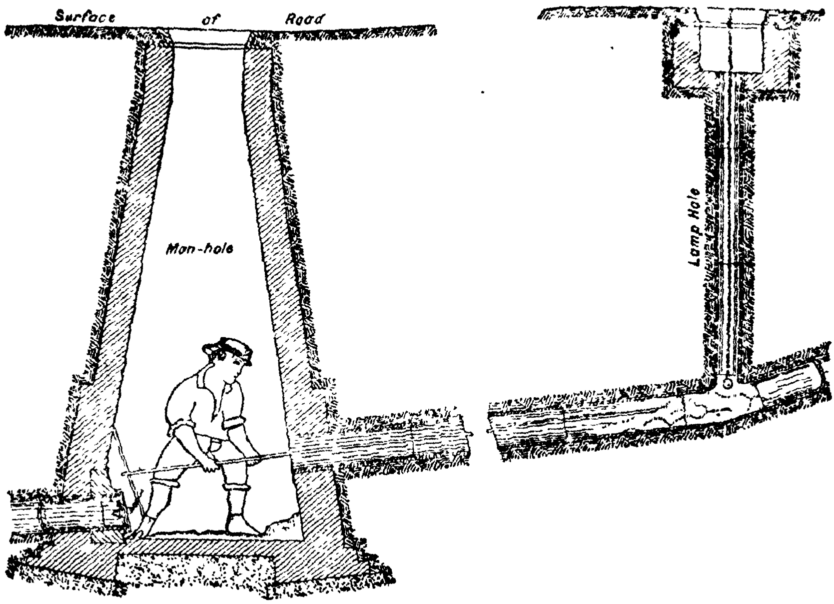
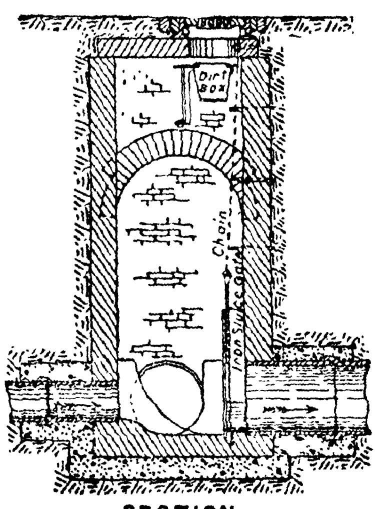
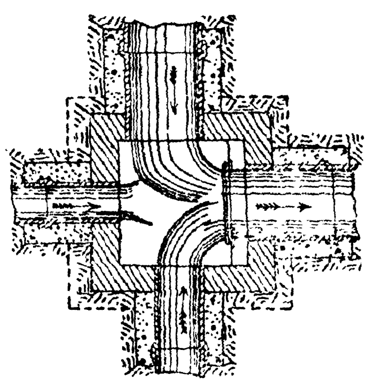


Fig. 12



SECTION.



PLAN.

It is desirable to plaster manholes inside with a half inch coat of cement and sand in equal parts to keep them absolutely water-tight.

23. **Construction of sewers and pipe lines.**—In laying pipes they should first be fitted dry in the trench prepared for them, all junctions for house connections, etc., being placed in position as may be required. They should then be aligned and boned to ensure their being laid true to line and gradient. A tarred gasket of hemp, prepared in one length for each joint, should then be inserted into each socket, passing completely once round the spigot end of the pipe and driven well home to the base of the socket, filling it to a depth of about one quarter of its length. Portland cement mortar is then forced into the joint until the whole space is filled up. *Fig.* 13.

There are many patent joints for stoneware pipes in the market. They are all expensive but under certain conditions some of them are very useful. Not being so rigid as cement joints they are not so liable to fracture by slight settlement in soft ground or by change of temperature. They can, moreover, be made very rapidly. They are made by forming on the inside of the socket and the outside of the spigot, rings of a mixture of ground stoneware, sulphur, and tar. The rings are specially shaped and fit exactly into each other. Before connecting the pipes the rings are tarred or greased. The spigot is then introduced into the socket and when in position a slight twist completes the formation of the joint. Impermeability of the joints is still further secured in the Hassell joint by inserting cement between the two sets of rings. *Figs.* 13 and 14 show a plain joint and a Hassell joint. There are other varieties of special joints but they are all on the same principle so they will not be described here.

Fig. 13.

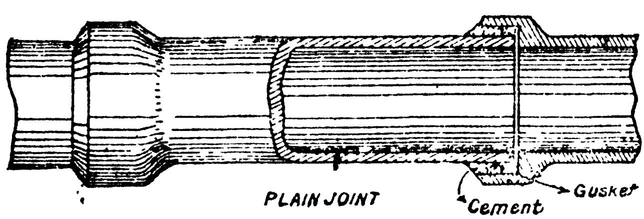
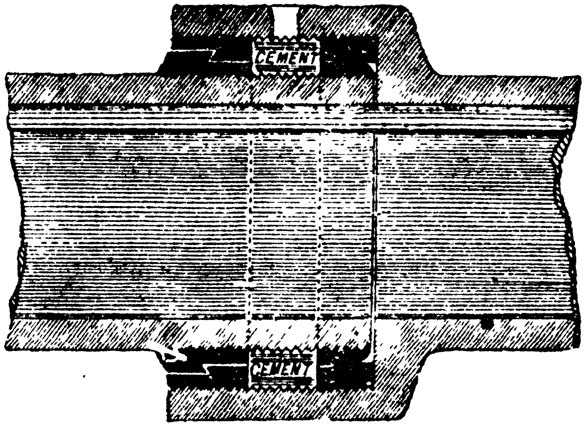


Fig 14



HASSELL JOINT

Pipes should not be laid at too great a depth without a protection of concrete to resist the pressure of the earth. A depth of 15 to 16 feet is about the limit for 9″ earthenware pipes, and 12 feet for larger sizes. Pipes laid at a greater depth should be encased in 6″ of lime or cement concrete. Earthenware pipes laid at a shallow depth below roads subject to heavy traffic also require a protection of concrete to prevent rupture. See paragraph 13.

After the pipes have been laid and jointed and before the trench is filled in, the "disc" and water tests should be applied to each length between manholes as described in paragraph 59, Chapter V.

24. The methods of constructing brick and cement sewers differ somewhat. The bottom of the trench is sometimes excavated to the shape of the lower part of the sewer and the brickwork or concrete is then put in round wooden templates and centers formed to the internal shape of the sewer; in other cases, the sewers are built up in blocks of brickwork or concrete moulded in masses of convenient size for handling. The former method is the one usually adopted in India.

25. The rule for the width of trenches is that they should be 2 feet wider than the greatest diameter of a pipe or sewer. If the ground is soft or sandy which will not stand with vertical face, or if the excavation is to be carried down a great depth the sides of the trench have to be carefully shored. No fixed rule can be laid down for the maximum safe depth of unshored trenches as this depends entirely on the character of the soil met with. Some loose soils will not stand more than 3 or 4 feet of excavation,

while others can be safely dug down 10 feet or more without timbering. In stiff clay a good deal of cross support is often obtained in trenches of moderate depth by leaving lengths of 5 feet unexcavated every 15 or 20 feet to act as struts. These are tunnelled under when the sewer is being laid. When excavations exceed a depth of 20 feet or so, it may be found cheaper in good ground to tunnel or run a heading in the ordinary way.

The following figures show the three ordinary methods of timbering a trench. *Fig.* 15 is shoring of the simplest kind. The walings (W) are strutted across nd vertical props (P) are added in some cases to hold up the walings. The trench being wider at the top, the timbering cannot well slip downwards, and, if there is any tendency to slip at all, it must tighten up still more against the sides of the trench. If it is desired to provide a wider support to the soil than the walings afford, poling boards are put in as shown in *Fig.* 16. In very bad ground close timbering as shown in *Fig.* 17 is used, the poling boards taking the form of vertical runners behind the walings. Instead of timbering, corrugated sheet iron frames are often used on the Continent for supporting the sides of trenches. These, being lighter, are fixed in position and removed more quickly, and in some places, where timber is scarce they may even prove less expensive.

Fig. 15.

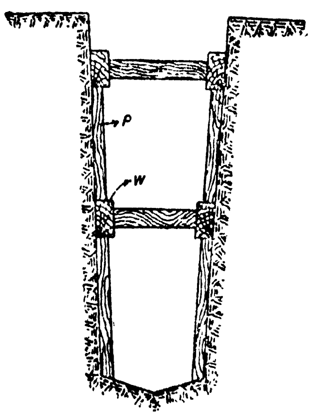


Fig. 16.

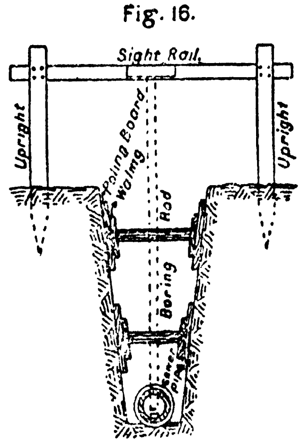
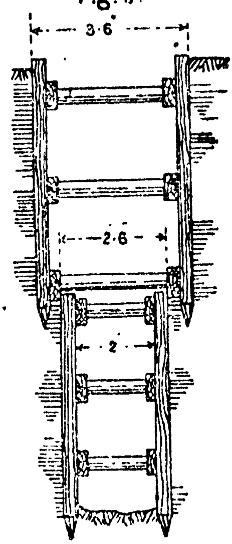


Fig. 17.

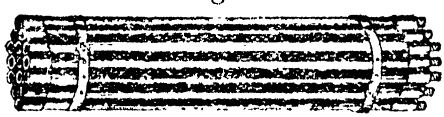


If water is met with in the trenches, it must be run into a sump hole at one end of the trench and pumped out to enable the work of construction to proceed in dry ground. If the bottom of the trench is soft and muddy, dry rubble should be rammed down first to a depth of 9″ or so and

on the rubble should be placed a layer of good concrete to form a secure foundation for the sewer.

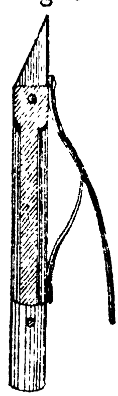
26. **Clearing obstructions.**—As already explained, sewers and pipes are particularly liable to obstruction in India as they carry large quantities of grit owing to the native habit of cleaning their domestic utensils, etc., with earth. Blockages sometimes take place in spite of flushing and it becomes necessary to resort to cleaning operations to remove deposits. For pipe sewers a double disc, consisting of two circular pieces of wood held a foot apart by four bolts is dragged through from one manhole to another, the silt being removed by hand at the manhole to which the double disc is drawn, or a cleaning apparatus of bamboo cane rods is used which are flexible and screwed together in lengths of about 4 feet. The latter have special attachments in the shape of springhooks, worm screws, scrappers, brushes, etc., By the use of rods, lengths of 200 feet can be cleaned without opening up the ground and breaking the pipe line. *Figs.* 18 to 22.

Fig. 18



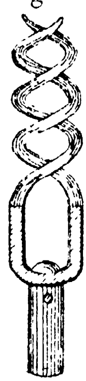
Cane Rods

Fig 19



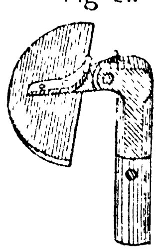
Spring hook.

Fig. 20



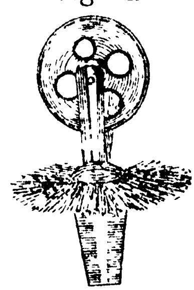
Worm Screw.

Fig 21.



Jointed Scraper

Fig. 22.

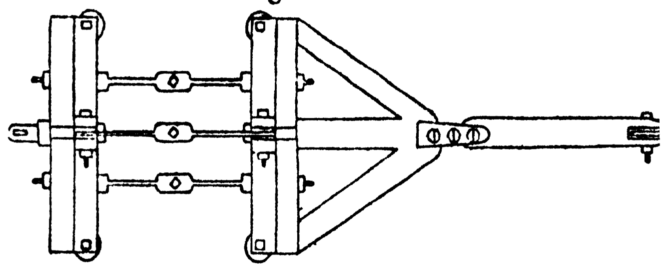


Brush and Wheel

For large brick sewers of ovoid shape, a scraper is drawn through by means of a winch and chain. It consists of two pieces of wood shaped to the inner curves of the sewer and provided with guide rollers at the top and bottom as also at the sides. They are of a size which gives about $1\frac{1}{2}''$ play all round. The Bombay type of scraper is shown in

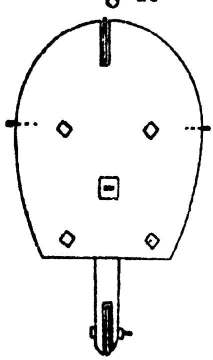
Figs. 23 to 25 which have been taken from "Oriental Drainage," by C. C. James. They are made in two patterns: one with the bottom part cut off and the other with the top cut away about a third of the distance down. When the scraper is dragged through from manhole to manhole, the sewage rushes through with an increased velocity either over or under the scraper and softens the deposit in front which is pushed along either into a catchpit or onwards to the outfall.

Fig. 23.



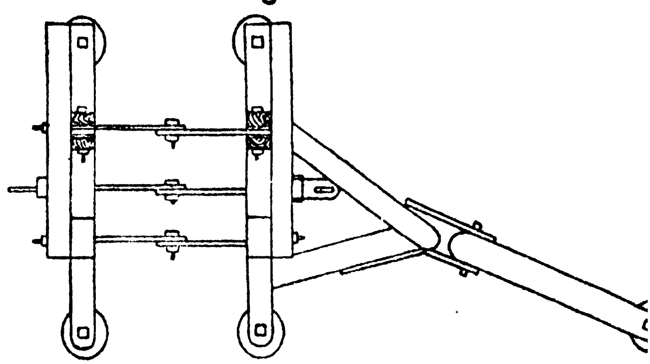
PLAN.

Fig. 25.



END ELEVATION.

Fig. 24.



SIDE ELEVATION.

In sending sweepers down in manholes to clean pipes and sewers, it is very necessary to see that the covers of the manhole to be entered and two at least on each side have been removed for some time, and that the sewer has been thoroughly ventilated before the men enter, as strong sewer gas in a foul drain is highly dangerous to life and might cause death by asphyxiation. In large foul sewers, the additional precaution should be taken of forcing in fresh air for at least 10 minutes before entry by means of an air pump or blast fan and a flexible air tube.

27. **Ventilation.**—The efficient ventilation of sewers is one of the most difficult and most important questions a Sanitary Engineer has to deal with. It is not only necessary to provide sufficient ventilation, but it is essential that it should be so carried out as to cause no nuisance.

Sewer gas generally consists of carbon dioxide or choke damp (CO_2) marsh gas (CH_4) sulphuretted hydrogen (H_2S) Ethyline (C_2H_4) ammonia (NH_3) and nitrogen (N). These are all the products of decomposition or putrefaction. Carbon dioxide and sulphuretted hydrogen are very poisonous gases, and, if present in large quantities, they cause instantaneous prostration, often followed by death; if mixed freely with fresh air they are comparatively harmless. Carburetted hydrogen and marsh gas are due to the decomposition of vegetable matter; the former is very explosive when mixed with atmospheric air, and for this reason naked lights should never be carried into sewers till they have been thoroughly ventilated and tested; marsh gas is combustible and burns easily with a blue flame when ignited.

28. Sewer gas undoubtedly lowers the vitality of human beings and predisposes them to disease, though there is no definite proof that it is the direct cause of zymotic disease. Fresh sewage, however, offensive, is practically harmless but it becomes progressively noxious and injurious when it begins to putrefy in its passage through sewers.

29. To ventilate efficiently it is necessary to provide both inlets for fresh air and outlets for foul gases. Ventilating shafts are ordinarily fixed at certain intervals along the course of a sewer and these act sometimes as inlets and sometimes as outlets according to the relative temperatures inside sewers and above ground, the rise or fall of the water level in the sewer and the force and direction of wind for the time being. The latest practice is to make all manholes in inhabited parts air tight and allow the ventilating shafts to act as inlets or outlets according to the conditions prevailing at the time.

30. Ventilating shafts should not be less than 6" in diameter for the smaller size of sewers, and their size should increase in proportion to the size of the sewer they ventilate. Their distance apart should ordinarily be about 500 ft. They generally consist of high vertical cast iron pipes carried up well above the window level of the highest houses in the vicinity. They should be as far removed from dwellings as possible, but in crowded parts they have to be fixed against the walls of street houses, *Fig.* 26. In the latter case they should be placed so that the sun will shine on them the greater part of the day as, if heated, they have the effect of creating a draught from the sewer. All the joints of a ventilator

should be carefully made to prevent the escape of gas near street level or the windows of the houses to which they are attached. The top should be provided with a cowl, or, at least, wire netting to prevent birds building nests in them. When the ventilator stands out in an open street without any houses in the vicinity to attach it to, it is made more ornamental and if possible utilised as a lamp post or sign post, *Fig.* 27.

Fig. 26.

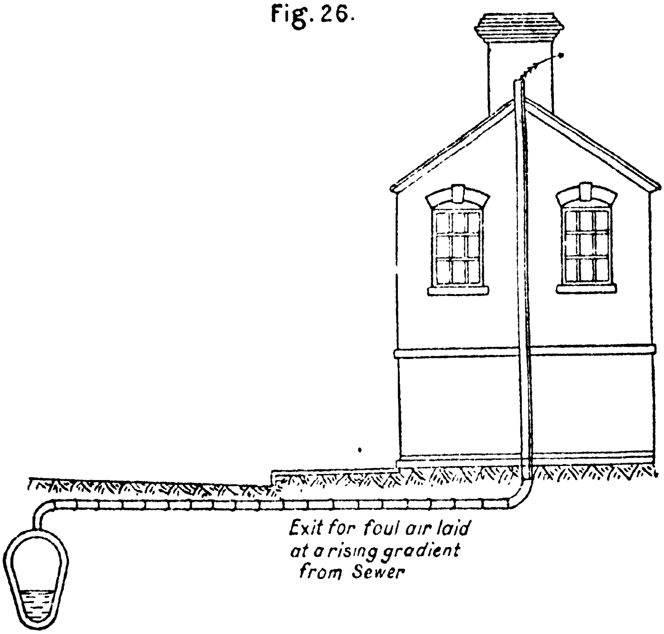
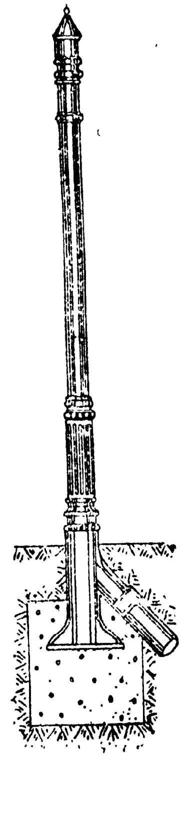


Fig. 27



The ventilation of the sewers in the highest part of a system, if there are considerable differences in level, should be ample and most carefully considered, as sewer gas tends to rise to the upper parts when the flow is more or less uniform; while, on the other hand, the lower parts must be equally well provided for to guard against the rush of gas towards the outfall with the flood water of heavy storms which tends to carry the gas with it by friction in its rapid descent from the higher parts.

Manhole ventilation might be provided on outfalls in open country where the gas is not likely to be a nuisance to those who reside in the vicinity.

31. **Outfall sewers.**—Outfall sewers deal with the discharge of the whole of the drainage of the districts they serve and consequently remain uniform in section thoughout their whole length except where gradients are altered or storm overflows are introduced. If they carry a large volume of sewage they are usually made circular in section. In other respects they are designed on exactly the same principles as the main sewers of the town.

The outfall may deliver the sewage (1) by gravitation or by lift to a sewage farm or to biological disposal works, (2) into an inland river, (3) into a tidal river or the sea. The first case is an ordinary one and needs no special remarks here as it is dealt with in other parts of this Manual. In the second and third cases, the lower end of the outfall is liable to be covered for a certain length by a rise of water in the river or sea.

In the case of an inland river, this will only occur during high floods and the submergence will be of rare occurrence and short duration so no special precautions are necessary but the invert of the outfall at its termination should be placed as high above low water as the levels will permit, consistently with other considerations, in order to reduce the periods of submergence as far as possible. An inland river can only be utilized as an outfall for untreated sewage if the volume of water in it at all times of the year is very large as compared with that of the sewer and there are no towns or villages immediately below the outfall. If these conditions do not obtain, the sewage must be treated before it is turned into the river as explained, in Chapter VIII.

For sewers discharging into tidal rivers or the sea, special measures are required, as it would be objectionable to discharge the sewage with a rising tide. In these cases the sewer ends are furnished with a flap valve which opens to pressure from the sewer side, but closes against external pressure from the rising water of the river or sea, and the lower length of the sewer is made large enough to store the sewage while the outlet is closed, *Figs.* 28, 29. The enlargement of the sewer is below the invert level to avoid interferences with the flow of branch sewers. The enlarged portion is thus converted into an elongated tank which receives the sewage during the period the sewers are tide locked *Fig.* 29. When the tide flap is opened, the impounded sewage runs through with a velocity

which cleans the sewer of any deposit that may have taken place during the period of stagnation.

Fig. 28.

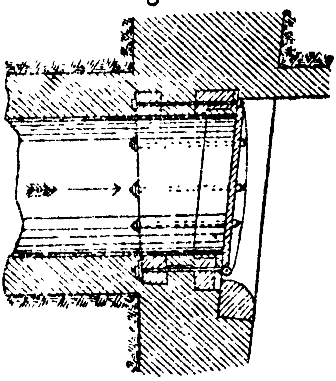
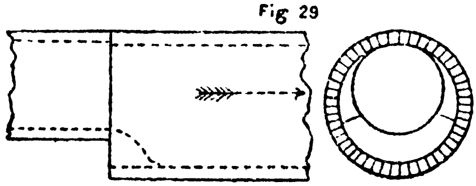


Fig 29



In order to reduce the large dimensions of outfall sewers to the lowest practical limit, it is advisable to introduce a storm overflow as near their commencement as possible to divert any excess storm water which may have entered the system beyond the quantity it is decided to carry on to the disposal work, river or sea, into the nearest natural drainage line by an inexpensive earthern channel. See *Plate* II.

32. **Sub-soil drainage.**—If the town stands on ground which is damp or water-logged, advantage should be taken of the construction of underground sewers to drain the sub-soil as far as possible and so make the site drier and healthier. It is not always safe to do this by making openings into the sewer for sub-soil water, as it may happen that instead of the water entering the sewer, sewage will pass out into the sub-soil, under certain conditions. The usual practice is to fill the sewer trenches to the top of the sewer with clay or other impermeable material and above this for a depth of 3 or 4 feet with loose gravel or broken stone, *Fig.* 30, which will allow of free percolation through the trench itself to the nearest outlet into a natural drainage channel. In some cases it may be found preferable to substitute for the gravel, one or two lines of open-jointed agricultural drains laid immediately above the sewer as shown in *Fig.* 31

Fig. 30.

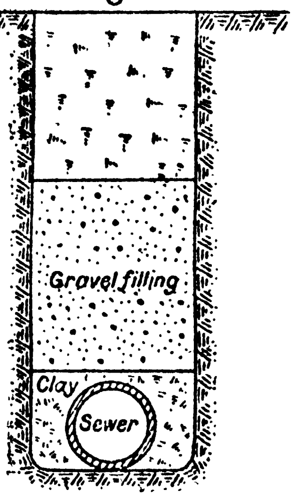
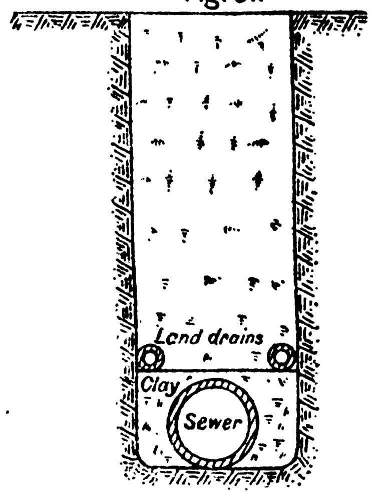


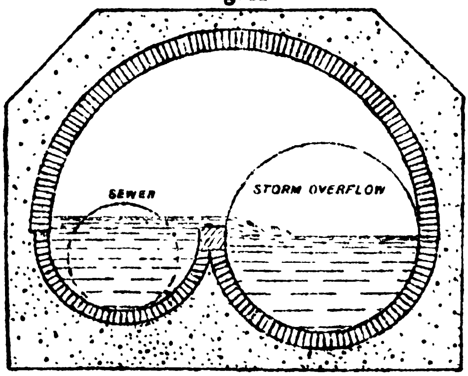
Fig. 31.



33. **Storm overflows.**—To relieve the sewers of the discharge of storm water in excess of that which they are intended to take, it is necessary to provide storm overflows at suitable points which divert a portion of the excessive discharge into the nearest natural drainage channel or the sea. See *Plate* II. A storm overflow consists practically of a large chamber enclosing the sewer and the head of the storm water channel. The latter receives the surplus water of the sewer over the crest of a longitudinal weir between the two when the water in the sewer has reached the desired limit and conveys it to some convenient outlet. *Fig.* 32 is a section of the chamber showing the sewer and its relief channel. The sectional area of the mouth of the sewer taking off from the lower end of the relief chamber should be only just sufficient to admit the discharge the sewer is intended to carry beyond this point. The length of the weir should be calculated to give the required discharge of storm water over the crest at the depth allowed.

An overflow from an open foul water drain into a storm escape is designed on the same lines, the cover being omitted.

Fig. 32



CHAPTER IV.

SURFACE DRAINS.

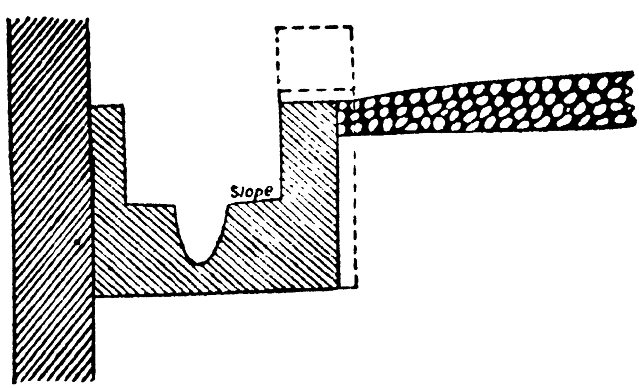
34. Alignment.—For the reasons explained in paragraph 3, Chapter I, the branch drains in the side streets are usually surface drains in Indian towns, underground sewers being reserved for the main valley lines. The alignment of sewers is regulated by the considerations detailed in Chapter III. They generally follow main streets in or near natural drainage lines. The alignment of branch surface drains is in most cases practically unalterable as they must be in existing streets, but it is necessary to ascertain from the levels the direction in which they will flow and the drainage block in which they should be included. When the map referred to in paragraph 11, Chapter III, has been plotted and all the required levels have been marked on it, the whole area of the town should be divided into drainage blocks or sub-divisions, the discharge from which falls into a separate sewer or main drainage line. This can be done roughly in the drawing office from the levels marked on the map but it is a better plan to go over the ground, map in hand, and mark down from inquiry and actual observation on the spot the lines of highest levels which form the boundaries or water sheds of each drainage area. Having fixed the boundaries of the several blocks into which the area is naturally divisible and marked them on the map, the lines of branch drains in each street to be drained must be marked in each block, commencing from the watershed end and working down to the sewers or main drainage lines. When all the drains in the different blocks have been thus marked it will be possible to calculate the area drained by each sewer and drain, and from these areas, allowing for a rainfall of $\frac{1}{4}''$, or whatever it may be decided to provide for, the sizes of sewers and drains required to suit the falls available will be estimated as explained further on. See *Plate* II which shows these drainage areas and the alignment of sewers and drains in them.

35. Slopes.—As main sewers carry fairly large discharges, there is no great difficulty as a rule in giving them the slopes required for self-cleansing velocities, but the branch-drain conditions are different. They carry but little sullage and are often in lanes which are flat or nearly so. On the whole, it will be found in most towns that the levels are such as to admit of fair slopes being given to such drains, but the falls are irregular and require a good deal of adjustment by the Engineer to secure the

best results possible. It may be necessary in some places to raise the level of streets for considerable lengths and in others to cut them down to get good working slopes for the side drains.

In raising streets, great care has to be taken to see that they are not made so high as to place them above the floors or courtyards of the adjoining houses which drain into them. It will be possible in many cases to arrange with householders to raise their floors or courtyards to bring them above the level to which it is desired to raise the street, but if this is not feasible there are only two alternatives open. One is to be satisfied with a flatter gradient than is desirable in the particular street in which the difficulty has arisen and the other to exclude the spot or spots which are too low from the benefits of the scheme, and raise the street, as may be necessary, to make it fit into the general system. Except in special cases, the former course will probably have to be followed, extra flushing and scavenging being relied on to keep the drains clean. When it is necessary to cut down streets, it will be necessary to ascertain carefully the depth of foundations of the houses on each side to see that the street and its side drains are not carried down so low as to endanger the safety of the buildings. The lowering of streets can often be avoided or reduced by making the side drains deeper with side walls, as shown in the sketch below, but this adjustment can only be carried out to a very limited extent, as open side drains in a street become dangerous and objectionable if they are more than 2 ft. deep. Where deeper drains are unavoidable, a substantial guard wall on the inner site is absolutely necessary as shown by dotted lines on the sketch, *Fig.* 33.

Fig. 33



The flattest ruling gradients for branch surface drains of peg-top section to carry up to ¼" rainfall should be 1 in 200 for the smallest size

at the upper ends where they begin, and they might get flatter gradually as the volume of flow and the size of the drains increase towards the outfall. The steeper the gradient the better, especially at the heads of drains where the flow of sullage is a mere trickle the greater part of the day. In most towns it will be found that this ruling gradient is available by careful adjustment of levels in different parts of the system, but there may be a few places where it cannot possibly be secured and in such places it will be necessary to adopt the best fall available and trust to extra flushing and scavenging to make up for the defect.

36. **Sections.**—As regards the best form of channel for surface sullage drains, it should be noted that during the rains the drains will often be running quite full, while during the dry season of the year there will be merely a trickle of water in them. If a drain is to be clean and inoffensive, the velocity of flow in it for a certain period each day, if not throughout the 24 hours, must be such that it will scour away and carry off all the filth and grit that may be deposited therein. From their knowledge of hydraulics, students will understand that in a circular section the maximum velocity occurs when it is more than half full and that the mean velocity diminishes very rapidly with the depth when the water line falls below the diameter. The diminution of velocity in a rectangular section is still more marked as the water line approaches the bottom. The best form of channel to give a fairly constant velocity for small depths of flow is that generally known as the peg-top section.

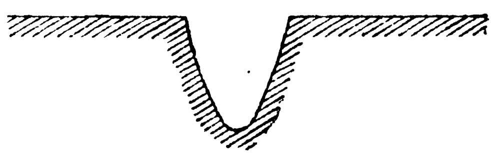


Plate III shows a series of drains of this pattern adopted for drainage schemes in Bengal. They are cheaply constructed and are said to have acted very well. The drain consists of a bed of concrete and two sloping side walls of brickwork, the whole inside surface being plastered with cement. For the side walls it is necessary to cut bricks on the inner side, but this is considered rather an advantage than otherwise as the face is plastered and the rough cut surface is better for the cement plaster to adhere to. The discharge of these channels can be calculated readily from Bazin's or Kutter's formula. The same plate shows a similar series of sections adopted for drainage schemes

in the United Provinces. These are more durable but somewhat more expensive. The inverts are specially moulded cement concrete blocks with a smooth rendered face inside. The sides up to the height to which the daily flow of sullage rises are made of slabs of hard stone, or, where stone is not procurable, of moulded cement concrete. Above the slabs, ordinary specially moulded bricks are used with their joints deeply pointed with cement. The side slabs and invert blocks are 18" to 2 feet long and present fewer joints than brickwork.

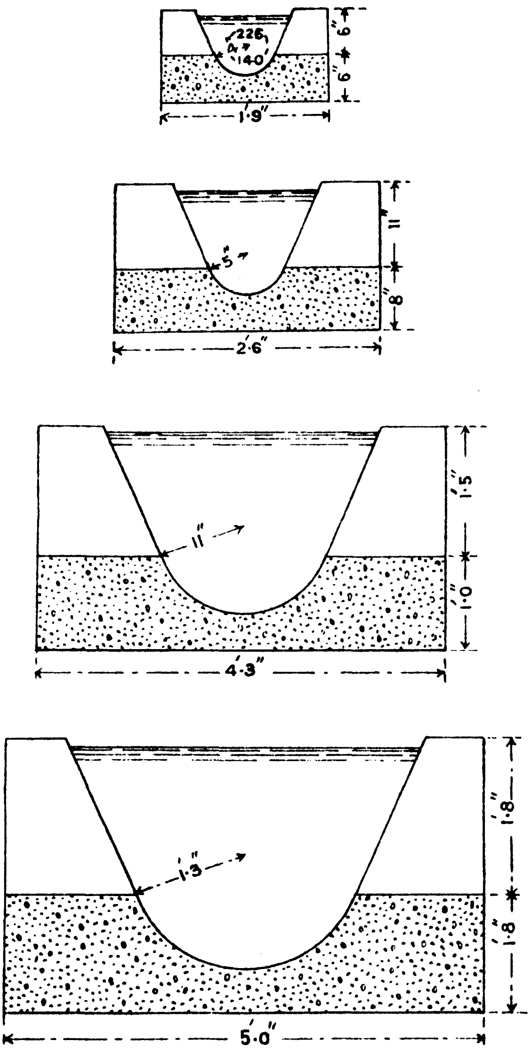
37. Having decided on the type of section to be adopted for a scheme, the Engineer will find it convenient in preparing a drainage project to compile for reference a table of velocities and discharges for each size, for different falls varying from 1 in 50 to 1 in 800.

38. The majority of the old existing drains in towns are either rectangular or saucer-shaped in section. In places they are large enough to carry off all the storm drainage or the geater part of it. Where such drains exist they might often be remodelled with advantage by forming a concrete cunette of the approved shape in their bottoms to take the sullage, leaving the upper part of the section to carry storm water as before.

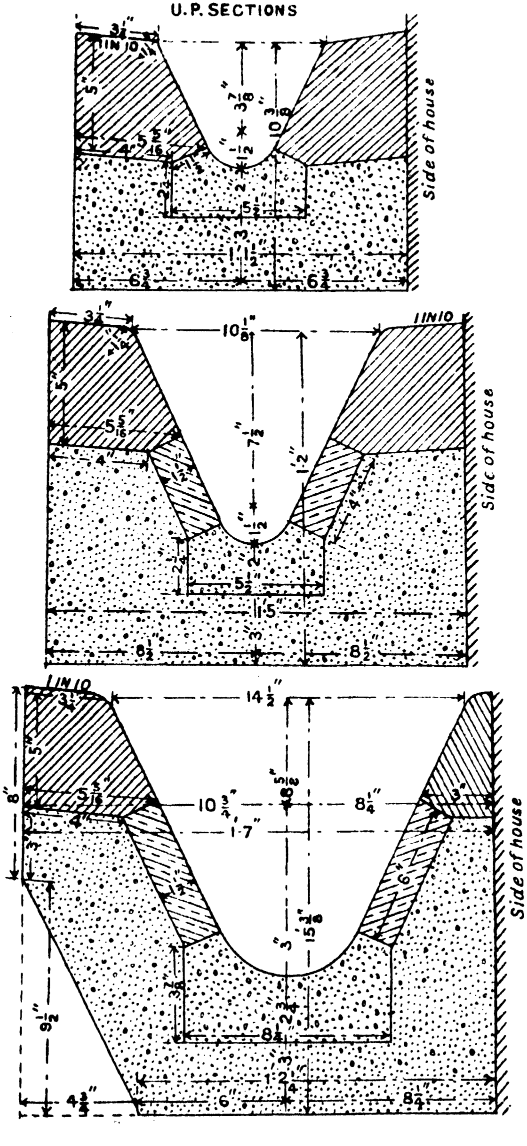
39. If, in certain cases, it becomes necessary to make the sullage drains large enough to carry all the storm water to drain a water-logged area which cannot be relieved in any other way and the section of drain required is so large that it would be too wide and to deep if made of the peg-top section, it might be built up with side walls above the sullage cunette as shown in *Fig.* 33.

40. **Provision for excess rain water not carried by sullage drains.**—Where sullage drains are only made large enough to carry ½" rainfall or less, the discharge from heavy falls of rain must be carried by the street ·al as it always has been, unless the excess can be diverted to some existing drain or a natural outlet. Where this occurs, the street surface should always be paved or metalled across the whole width to protect the drains from injury. Paving of bricks or stone is generally resorted to for narrow lanes in which there is only foot or ekka traffic, and metalling for wide streets which carry heavy cart traffic. In such places, the walls of houses against which the drains abut should be plastered and carefully protected to avoid damage to the foundation by the overflow from the drain. In narrow paved lanes, a central drain is usually provided, instead of a drain on each side, with groove connections across the paving from the house drains. Sometimes a

BENGAL SECTIONS



U.P. SECTIONS



single drain is provided on one side only with cross connections from the house drains on the other side. See *Figs.* 34 and 35.

Fig. 34

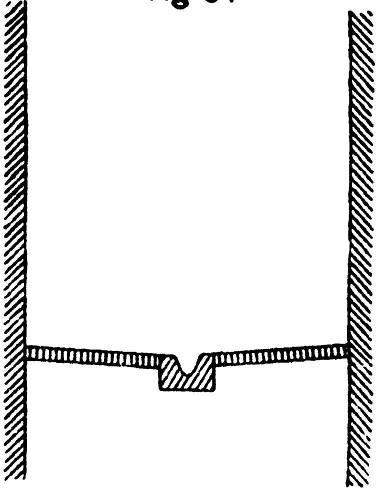
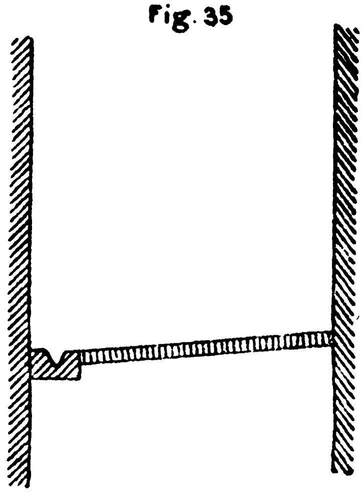


Fig. 35



41. **Covering surface drains.**—Where surface drains are used, it is very necessary to see that they are kept uncovered everywhere as far as possible for convenient scavenging and inspection. The covering of drains for shop platforms and house steps should be restricted to the lowest possible limit. When surface drains are covered in short lengths, they usually become receptacles for street sweepings which the conservancy staff are often too lazy to remove.

42. **Flushing and cleaning surface drains.**–If surface drains are to be kept clean and wholesome, they must be thoroughly flushed daily; this is usually done for the smaller branches, where flushing tanks are not provided, by "bhistis" pouring water slowly into a drain behind sweepers who move forward and carry all deposits before them by means of brooms. A better way, when the slopes are not very steep, is to divide the lengths into section of 100 feet or so by boards dropped into grooves formed in the sides of the drain and to flush each length by suddenly removing the board and admitting a full flush from the section above. The first length at the head of the drain having been cleaned is filled with water as high as possible and when the board at the lower end is quickly removed the impounded water moves forward with a rush carrying in front of it all objectionable matter that has been deposited in the drain. The next length is filled

with the water from the length above it and treated in the same way. When the flushing boards are lifted sweepers with a compact bunch of straw or grass should be standing at the head of the next length ready to stoop down and push the water in front of them, removing the solids as they go. This system leads to economy of water and is efficient if well done. Important branches or large sections should be flushed by flushing tanks at the head of each length as explained in the chapter on sewers and underground pipe drains. A flushing tank is not so useful at the head of a branch drain of a very small type as such a drain does not carry a sufficient volume to take the flush on at a cleansing velocity unless it is on a very steep slope.

43. **Junctions with underground drains.**—At junctions with underground drains, a water gully with a deep seal should be provided to prevent sewer gas rising into the streets. The depth of the seal should not be less than 9 inches on account of the rapid evaporation which takes place in India. See *Figs.* 10 and 61.

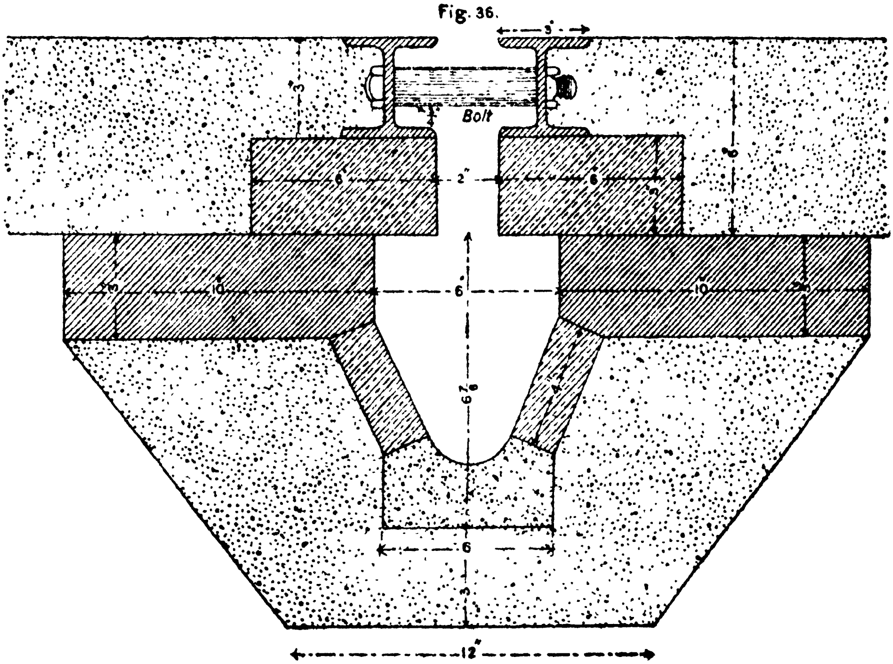
44. **Road crossings.**—At crossings of roads the surface drains should be covered as shown in *Fig.* 36. This arrangement allows all traffic to pass over without inconvenience, and at the same time leaves a groove 2″ wide over the whole length of the drain through which it can be readily examined and cleaned. The cross bolts securing the rolled joists at the surface are spaced about 3 feet apart and are provided with loose cylindrical jackets which act as distance pieces to keep the joists apart.

45. **Concluding remarks.**—In concluding this chapter, the author would draw attention to the fact that the surface drainage system here described cannot be considered an efficient substitute for an underground system under any conditions, and the most that can be said for it is that, if properly designed and managed, it is capable of giving good results in towns which cannot afford a complete sewerage system and are not provided with a liberal supply of water for flushing purposes without which an underground system cannot be worked satisfactorily. As soon as funds and a sufficient supply of flushing water are available, the surface drains should be replaced by underground sewers and pipes and, with this end in view, the main and intercepting sewers should be laid as deep as possible to allow of good slopes being given to branch sewers when these are put in later.

46. **Details of projects for surface drainage.**—Students are referred to the printed instructions issued by the Sanitary Engineer's Department of the United Provinces for preparation of drainage projects which give

full details of the report, specifications, calculations and drawings required for a surface drainage scheme See Appendix A.

Fig. 36.



CHAPTER V.

HOUSE DRAINAGE.

47. **Use of water closets in India.**—It will be many years before the use of water closets becomes general in Indian cities, as the habits of the people and their caste prejudices are opposed to it in many ways. In hotels, clubs and residences occupied by Europeans and the higher class of natives, the ordinary English method is usually adopted, but before it can be adapted generally to the peculiar conditions which obtain in India, the principles of the English method require some modification. The English system will first be described in this chapter, and then the adaptations necessary for Indian dwellings will be dealt with.

48. **Development of the water closet from the original to its modern type.**—When water closets were first brought into use little attention was paid either to their position or ventilation, and pan closets were generally used with a large basin underneath into which the pan discharged its contents. The sides of the basin could not be readily cleaned, and only a small portion of their surface was washed by the flush on lowering the pan; they consequently became very foul in time from deposit, from which an objectionable smell entered the house every time the pan was opened. With the closets placed well inside the house without any communication with the outer air the insanitary conditions which thus arose were most objectionable. See *Fig.* 37. The valve closet, which followed the pan type, fitted closely on the soil pipe and afforded an effective water seal with a more direct discharge into the soil pipe. It held up a large quantity of water as a seal in the basin, and, owing to the comparatively small size of the valve, it presented considerably less surface for deposits. See *Fig.* 38. All water closets and washing places in modern practice are placed against the outer walls of buildings, they are thoroughly trapped and ventilated and all moving parts have been eliminated from the closet. The basin and siphon water trap of the modern water closet are made of earthenware or porcelain in one piece and the whole of the pipe leading from the basin to the soil pipe is cleaned by the flush every time the closet is used. The wash-out pattern of closet made on this principle was the favourite a few years ago, and is still adopted by some Sanitary Engineers. See *Fig.** 39. In this pattern, the outlet of the basin is at the side and the siphon and water seal are hidden from view; but, to ensure an affective wash out, the water in the

Fig. 37. Pan Closet.

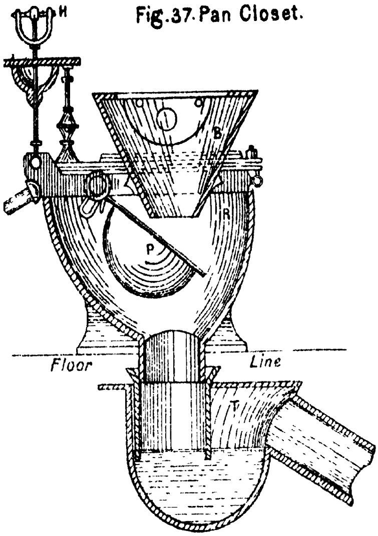


Fig. 38. Valve Closet.

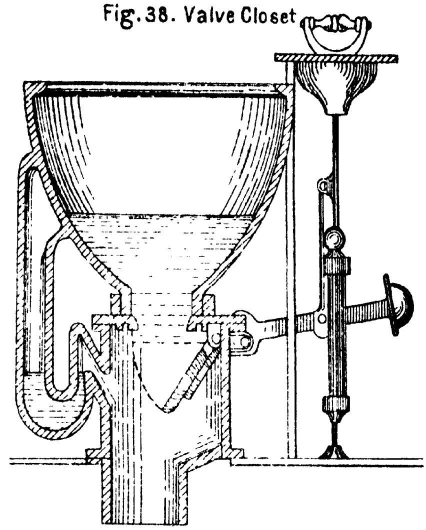


Fig. 39.

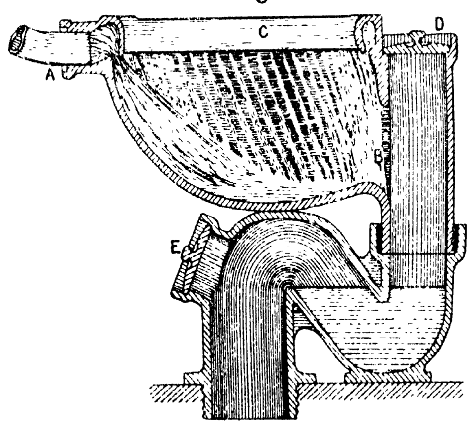


Fig 40.

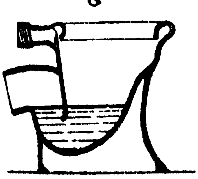


Fig. 41.

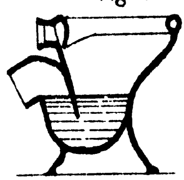
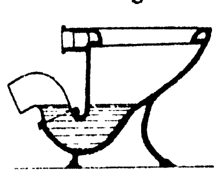
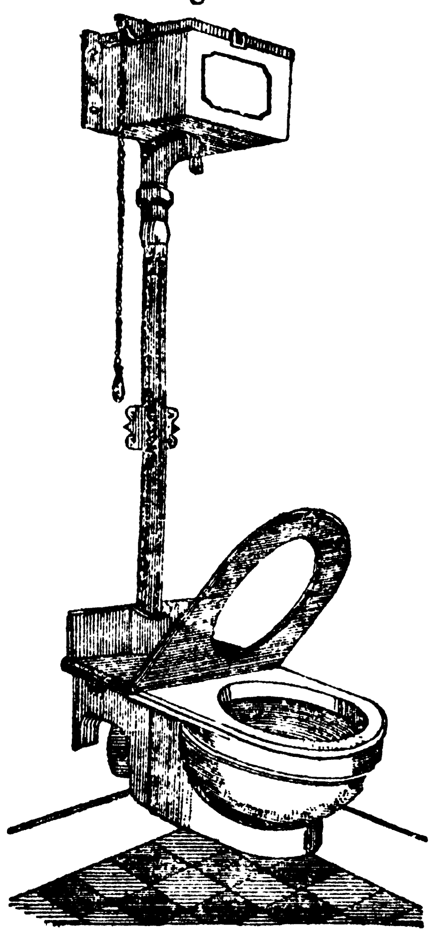


Fig. 42.



basins has to be shallow, the flush is apt to break up the solids in washing them out, and its force is directed chiefly against the far side of the outlet before reaching the siphon, while the length of pipe between the outlet and the water in the siphon is liable to become foul without being noticed. This once popular type has now been superseded to a great extent.

Fig. 43.



*"Sanitary Engineering" by Colonel Moore, R.E.

Modern water-closets are of many types, but the three types shown in *Figs.** 40, 41, 42 are those now used most commonly and are the simplest and the cheapest. A simple pipe leads the flush from the cistern into the basin of the closet to wash out the contents of the latter past the trap at the back into the drain. The three closets illustrated are similar in principle and differ merely in minor details. The closet shown in *Fig.* 40 has a larger water area than the other two, but a smaller seal; the one in *Fig.* 41 has a greater depth of water seal, while that in *Fig.* 42, besides having a seat projecting out further, is so arranged that it joins the soil pipe below the water level of the trap, thereby preventing any escape of sewer gas into the house through this joint and facilitating the discovery of any leakage there.

The mechanical working parts of a water closet of the old pattern were enclosed in a wooden casing, but the latest approved practice is to fix the closet with its pedestal completely exposed on a cemented or tiled floor to prevent the collection of dust and foul air and to render all parts readily accessible for cleaning and repairs. See *Fig.* † 43. A further advantage of fixing a water closet in this way is that by hinging the wooden seat at the back so that it can be readily raised the closet can be used as a urinal and as a slop receptacle.

49. **Water closet room and flushing arrangements.**—The room in which a water closet is fixed should be as small as possible (6′ by 4′ is ample) and it should be fixed against an outer back wall; it should be well lighted and ventilated by a large window of frosted glass, opening out into the external air and reaching nearly up to the ceiling, and air bricks should be introduced in the outer wall near the bottom and top to ensure the renewal of air in the chamber. A lobby or passage should always cut off the water closet chamber from the rest of the building. Each water closet should be flushed from its own cistern fixed a few feet above it, see *Fig.* 43. Flushing cisterns generally provide a flush of 2 to 3 gallons at a time. They are made in various forms, but *Fig.* 44 represents the type commonly used. This has a central siphon arrangement which is actuated by pulling a handle and rapidly discharges the contents of the cistern into the basin of the closet. The bell of the siphon, attached to the handle which covers the outlet pipe is raised when the handle is pulled and on being suddenly released, its descent causes the water to rise inside and flow down the outlet producing a partial vacuum which starts the

* "Sanitary Engineering" by Vernon Harcourt.
† "Sanitary Engineering" by Colonel Moore, R. E.

siphon. Once started, all the water in the cistern is drawn rapidly through the large openings near the base of the bell. The fall of the water level in the cistern when emptied causes the descent of the ball float and the consequent opening of the ball cock for the refilling of the cistern.

Fig. 44.

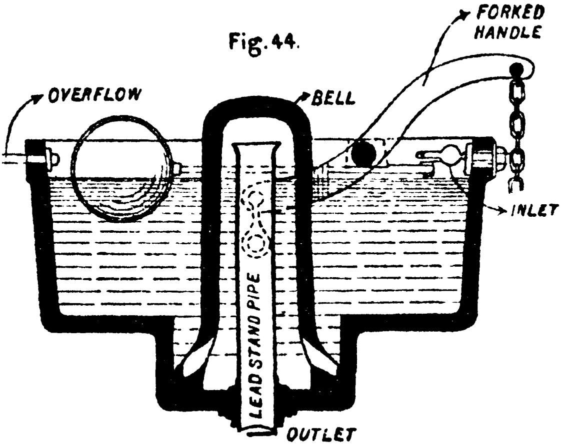
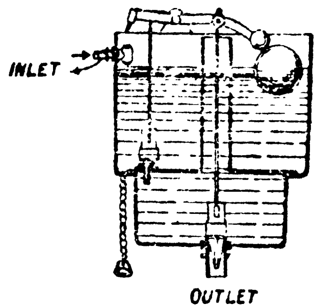


Fig. 45



The cisterns represented by *Fig.* 44 cannot be used again for flushing till they have been refilled, which takes a few minutes. If two or more flushes are required in rapid succession, the arrangement shown in *Fig.* 45 is usually adopted. The upper cistern is large enough to fill the lower one three or four times over through an opening in the bottom which is controlled by a plug valve. A similar valve is fixed on the outlet pipe at the bottom of the lower cistern. Ordinarily, the upper plug valve is kept raised and the two cisterns are in communication with the lower valve shut. When the handle is pulled, the lower plug is raised and the upper one shut down The lower cistern is thus rapidly discharged while communication between the two cisterns is entirely cut off. As soon as the handle is released a counterweight at the end of the handle lever raises the upper plug to its original position and depresses the lower one, allowing the lower cistern to fill again for another flush.

Flushing cisterns should be filled independently by an inlet pipe leading from the water main or house cistern and discharging into the cistern in the open air so that the supplies to the water closets may be entirely disconnected from the water supply to the house which is thus preserved from all danger of pollution. An overflow pipe should be fixed

from the highest water level in the cistern to the outer side of the nearest house wall in a position where any overflow from it is certain to be noticed and will act as a warning that the ball cock is not in good working order. These flushing cisterns are termed waste preventers because they prevent the excessive continuous use of water for flushing purposes, though they provide an ample flush every time the handle is pulled.

50. **Soil pipes and their ventilation.**—The pipe which receives the discharge from the trap of a water closet and conveys it to the underground house drain or street sewer is called the soil pipe. *Figs.* 46 and 47 show the connection of the water closet with the soil pipe. The former shows the method of connecting a single water closet on the ground floor, and the latter illustrates the junction with a common vertical soil pipe serving two or more water closets vertically above one another in a house of several floors.

Fig. 46.

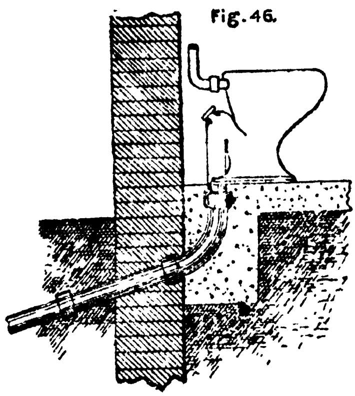


Fig. 47.

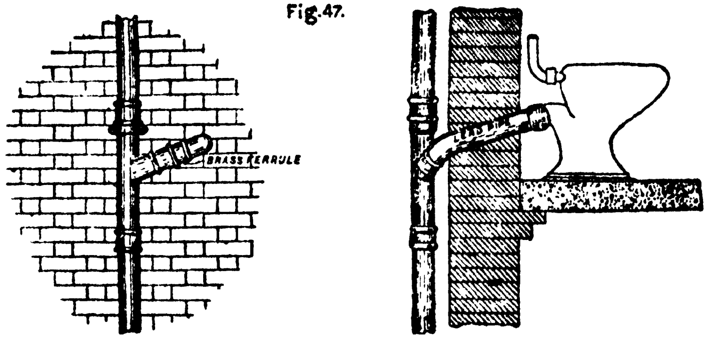
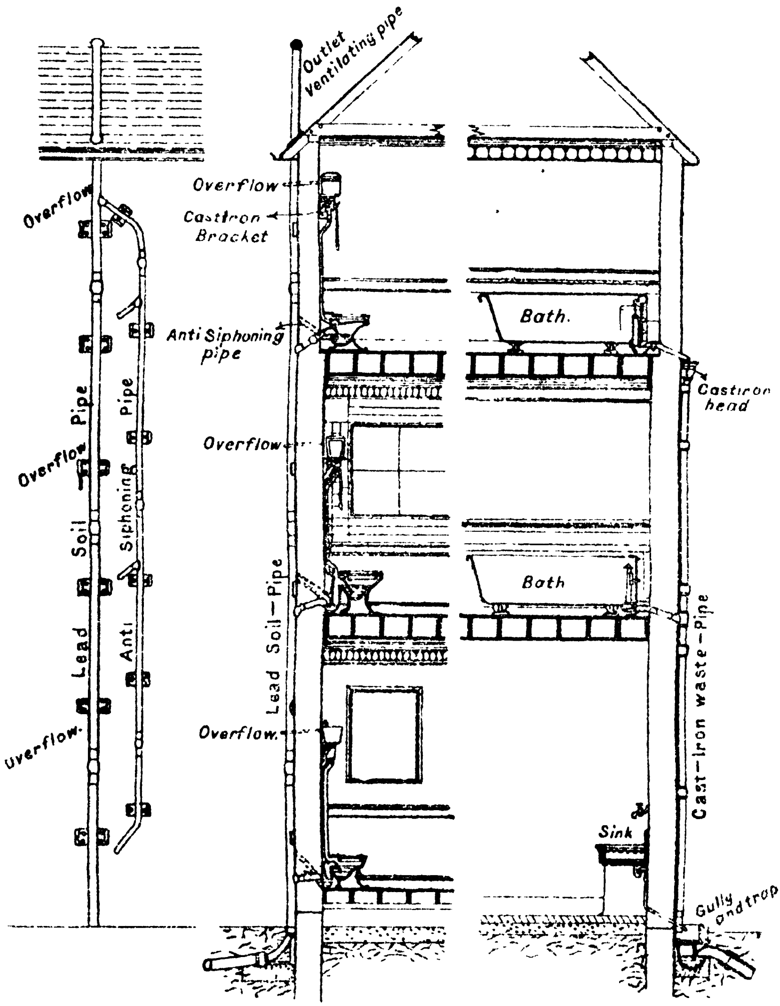


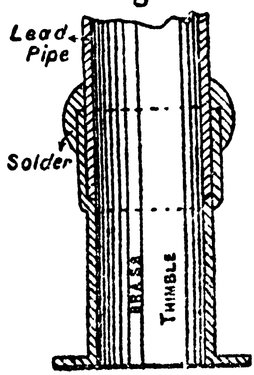
Fig. 49.



Overflow
Overflow
Uverflow.
Lead Soil Pipe
Anti Siphoning Pipe
Outlet Ventilating pipe
Overflow
Castiron Bracket
Anti Siphoning pipe
Overflow
Lead Soil-Pipe
Overflow.
Bath.
Bath
Castiron head
Cast-Iron waste-Pipe
Sink
Gully and trap

It is very important that the connection of the trap with the soil pipe is both air-tight and water-tight to prevent the leakage of sewer gas or foul water into the house. The connecting length between the water closet trap and the iron soil pipe outside is usually of lead, which, being soft, adjusts itself more readily to slight settlement or shrinkage of floor without rupture. A brass thimble is soldered to each end of the lead pipe to make a joint with the stone ware of the water closet on one side and the iron soil pipe on the other. The stoneware connection is made with Portland cement and that between the iron soil pipe and the thimble of the lead pipe is an ordinary lead caulked joint. *Fig.* 48 shows how the brass thimble is soldered to the lead pipe by a " wipe joint."

Fig 48.



The vertical soil pipe serving water closets on two or more floors is usually of cast iron. 4″ diameter, with lead joints, but lead pipes are sometimes used for the purpose. It runs into the house drain at the bottom and is carried up full bore to roof level to act as a ventilator, finishing, with an open end, well above the highest windows of the house. If cast iron pipes are used they should be thoroughly coated inside to protect them from the corroding effects of sewar gas. The upper end should be covered with copper wire netting to prevent birds building their nests in the pipe and blocking it up. In high houses where three or more water closets discharge into the same vertical soil pipe, the rapid downward discharge from the upper closets by creating a partial vacuum behind it, tends to produce a siphoning action on a traps in the lower closets and often unseals the traps by withdrawing the water from them. To avoid the risk of this occurrence, it is necessary to provide an anti-siphonage pipe, about 2½″ diameter near the soil pipe, see *Fig.* 49. This second pipe is connected with the soil pipe of each closet by a branch starting from this soil pipe beyond the trap, and by placing the water in each trap in direct communication with the open air, it prevents the water being sucked out of the trap.

51. **Urinals.**—Urinals inside buildings are objectionable from a sanitary point of view as it is very difficult to prevent them becoming

offensive and giving trouble, but they must be provided in residences in special cases, and they are often required in hospitals, schools and public offices. In ordinary dwellings, the modern water closet with raised lid makes a convenient urinal. The discharge from urinals is of a foul nature and should be led by the shortest route to the external soil pipe or drain with precautions as to trapping, flushing, and ventilation similar to those required for a water closet. The discharge from a series of urinals is usually through a short pipe into a non-absorbent glazed semi-circular drain covered by a removeable grating which can be taken up occasionally for cleaning the drain. This drain has a sharp fall and discharges into a gully at one end, from which it runs to the soil pipe or house drain, with ventilation and trapping arrangements the same as those of a water closet connection. See *Fig.**50.

Urinals require special flushing to prevent their becoming foul and emitting offensive odours. The usual arrangement is to provide each urinal or set of urinals with a small automatic flushing cistern set to discharge rapidly once every quarter of an hour or so. In addition to the periodical flush, a small weep hole is generally left in the cistern outlet to allow a very small flow or trickle to run through continuously to keep the basins free from smell and deposit. Urinal basins are usually of glazed stoneware and partitions and foot plates of slate, marble, or other non-absorbent material.

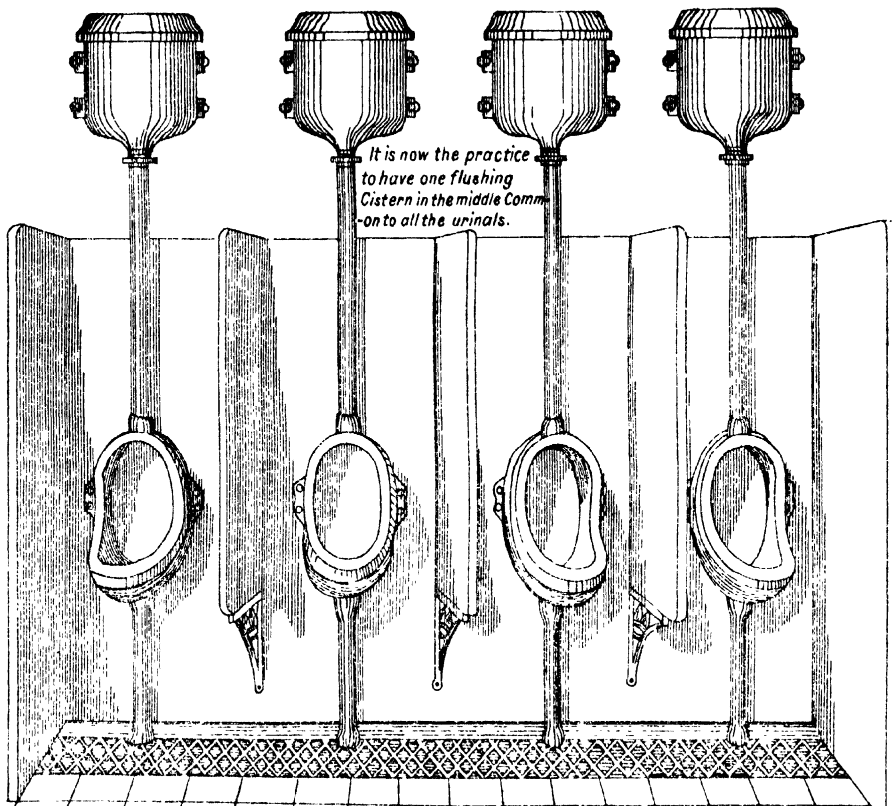
52. **Slop Sinks.**—These are intended to dispose of foul water from bed rooms or hospital wards and operating rooms, and require the same provision as water closets in the matter of flushing, trapping and ventilation. See *Fig.* 51.

Where modern water closets with a lifting seat are provided they serve conveniently for this purpose, and separate slop sinks are not needed.

53. **Baths.**—The waste from these is not quite so foul as the discharge from water closets, urinals and slop sinks, as it does not carry any excrementitious matter, and their outlet connections with drains are therefore not so elaborate. The discharge from baths usually consists of a large volume of only slightly soiled water, soap and other solids being excluded from the waste pipe by a grating at the outlet from the bath. It is generally passed, on emerging from the house, into a vertical lead or cast iron pipe about 2″ diameter, with a large open head. The external pipe

* "Sanitary Engineering" by Colonel Moore, R.E.

Fig. 50.


It is now the practice
to have one flushing
Cistern in the middle Comm-
-on to all the urinals.

discharges in the open air over a grated and trapped gully at the head of an underground branch drain. See *Figs*. 49 and 52.

Fig. 51.

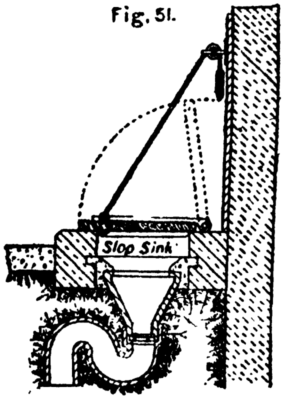
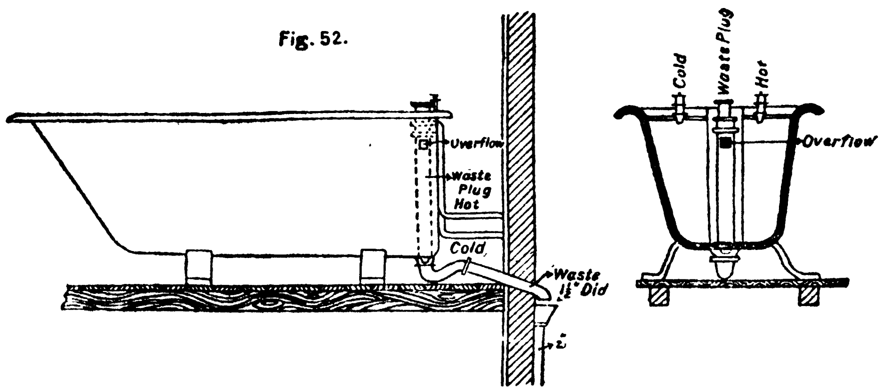


Fig. 52.

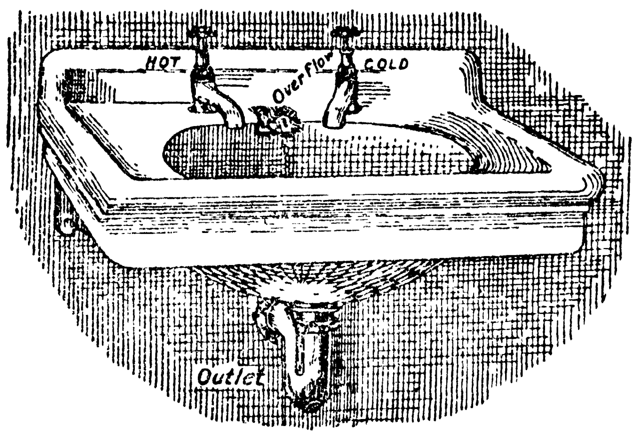


The short length of waste pipe (1½" diameter) immediately below each bath is trapped to keep out any offensive odour which may issue from this pipe in hot weather from decomposition of soap suds or other deposits. The mouth of the waste pipe in the bath is covered by a long hollow cylindrical plug which is raised by hand to open the waste and lowered on a rubber seat at the mouth of the outlet to close the waste and fill the bath. The overflow passes into the waste pipe through openings near the top of the hollow plug cylinder. The hot and cold water inlets run in at one end and each of these is controlled by a substantial screw cock at the top of the bath. Baths of the cheaper variety are made of cast iron covered with white enamel paint, but the better kind are of enamelled fireclay or porcelain enamelled iron.

54. **Lavatories.**—Lavatory basins are made of the same material as baths. They are provided with taps, overflows, inlets and outlets, very similar to those of a bath. See *Fig.* 53.

They are generally fixed in residential buildings in the same room as the bath and discharge into a common external waste pipe and gully.

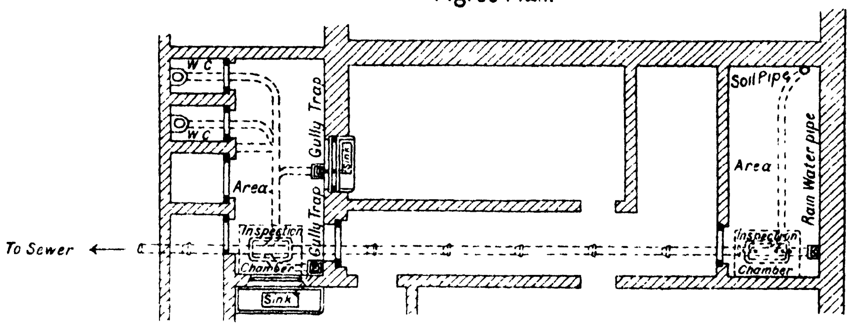
Fig. 53.



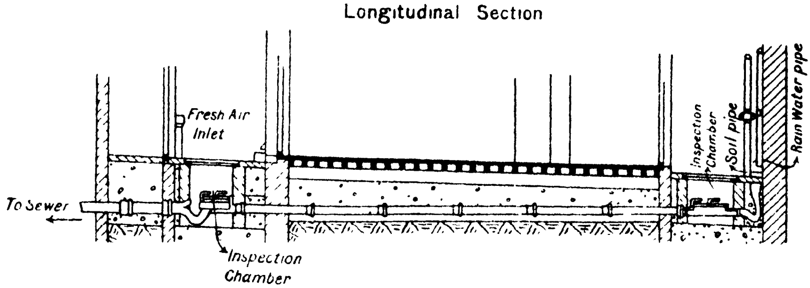
55. **Kitchen Sinks.**—These are treated in the same way as baths and lavatories as regards the connection with the external underground drains. See *Fig.**54. They are invariably placed against an outside wall, and under a window, so that the waste pipe is as short as possible and ample light is received for the washing operations. Scullery sinks in which kitchen dishes and utensils are washed are usually made of glazed stoneware, but the pantry sinks, in which glass and other fragile articles are cleaned, are generally a form of wood, lined with lead, as these articles

* "Sanitary Engineering" by Vernon Harcourt.

Fig. 55-Plan.

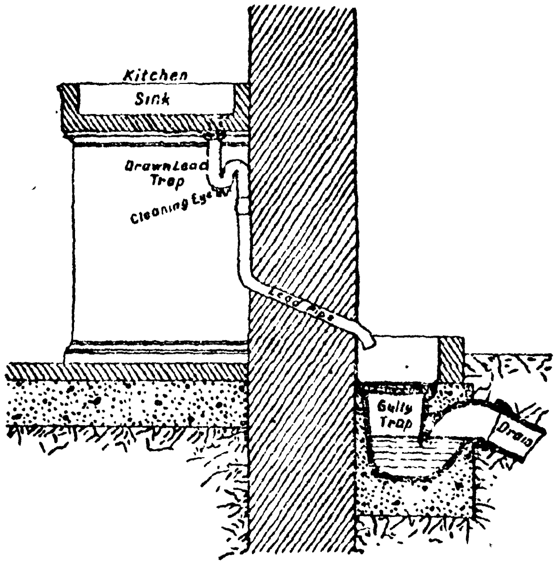


Longitudinal Section



are less likely to be broken by coming in contact with soft lead than with stoneware.

Fig. 54.



56. **House drains under buildings.**—In towns it is not always possible to place all the water closets, lavatories, sinks and other conveniences against the outer wall of houses adjoining the street sewer, and it becomes necessary to carry a drain under a house from back to front. In such cases, the drain pipes under the building should be of cast iron laid on a bed of concrete and jointed with caulked lead. This part of the drain should, if possible, be dead straight and on a sharp slope not less than 1 in 40. There should be an inspection chamber at each end, in which the different branches should make a junction with this drain. See *Fig.* *55.

* "Sanitary Engineering" by Vernon Harcourt.

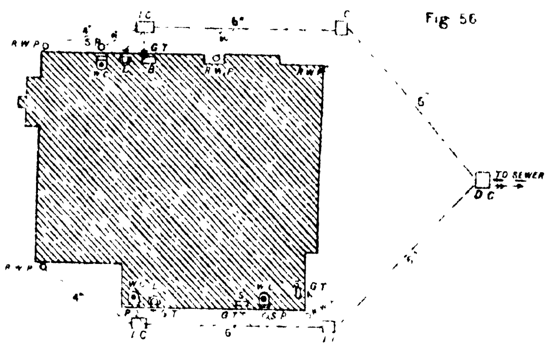
57. **Drains from houses to sewer.**—All the branch drains from water closets and sinks are usually 4″ earthenware pipe drains, and run into a common house drain 6″ to 12″ diameter, which runs into the street sewer in the most direct line possible. They are laid in straight lines on a firm bed and jointed with cement. At every bend, they are provided with inspection chambers, *Fig.* 56, and just above the point where they leave the premises to run into the public street or sewer a disconnecting chamber is formed to cut off the house system from the street sewer gases, *Fig.* 57. This chamber has a fresh air inlet to ventilate the house drains and a siphon trap at the lower end. If the connecting drain from house to sewer is of considerable length a 4″ ventilating pipe is usually fixed at the head of the drain immediately below the disconnecting chamber trap and carried up the side of the nearest house above roof level in the same way as vertical soil pipes are. See *Fig.* 62.

58. **Fall of house drains.**—All underground house drains should have a sufficient fall to carry away readily night soil and other waste matters which are admitted to them without the occurrence of deposit in the pipes. The falls required from drains of different diameters have been found by experience to be not less than 1 in 40 for 4″ pipes, 1 in 70 for 6″ pipes, 1 in 100 for 9″ pipes, and 1 in 150 for 12″ pipes. These gradients give a velocity of 3 feet per second when the depth of the stream of sewage is one quarter of the diameter of the pipe.

If the available fall is not quite sufficient to give self-cleansing gradients to all the drains of a system, the branch drains at any rate should be laid with self-cleansing gradients. The large drains into which they collect will thus have slightly flatter slopes and must be kept clear by periodical flushing which is more easily applied to a small number of large drains than to a considerable number of branch drains. The alignment of the drains should be so arranged in such cases that the branches are as short as possible, especially towards the head of the system, in order to economize the available fall. Special flushing may be dispensed with in some cases by fixing large outlets of 2½ or 3 inches diameter to baths or washing troughs, or by providing water closets with larger flushing cisterns than usual.

59. **Testing house drains.**—New drains should always be tested before they are brought into use. Soil and waste pipes above ground and connections with apparatus are tested with smoke or air under pressure. The "disc" and "water" tests are applied to underground drains before they are covered in. The former consists of passing a short cylinder or disc of wood about ½ inch less in diameter than the pipe through the whole

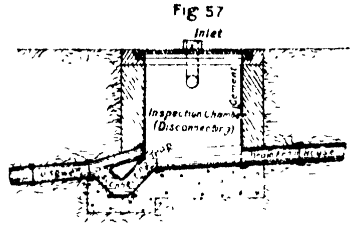
Fig 56



REFERENCES

Rain water pipe. . . ○R W P
Soil pipe. . . . . . ○S P
Gully trap. . . . . G T
Water Closet . . . W. C
Sink . . . . S
Lavatory L
Bath . . . . B
Inspection Chamber I C
Disconnecting do D C

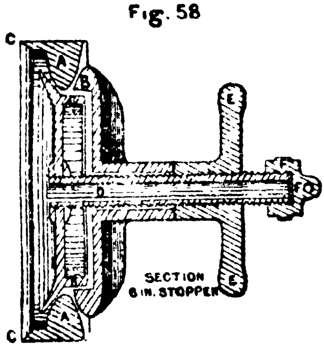
Fig 57



No 834·25

length to make sure it is clear of rubbish. The water test is made by plugging the lower end of the drain to be tested and filling it with water to ground level. The plug used is generally the Addison patent stopper, shown in *Fig.* 58. A is a rubber ring which presses against the inside of the pipe. It has a lip, C, which tends to make the plug more water-tight the greater the internal pressure of water on it. The rubber is held in position by the guide, B. There is an inside tube, D, sealed by a screw cap F, which when unscrewed, allows the water to escape after the test.

Fig. 58



AFTER EXPANSION

The expanding of the rubber ring is effected by screwing the nut, E. These plugs are supplied in different sizes from 4 to 12 inches. The most convenient place for applying the plugs is in inspection chambers or in the disconnecting pit above the trap. If the necessary test head cannot be obtained in any other way an Addison stopper may be applied at the upper end also and a piece of Indiarubber tubing attached to the brass tube through the centre of the stopper. The rubber tube can be filled with water to the required level through a funnel.

Plugs are usually inserted at the ends of the main house drain only and all branch drains are included in the test of the main drain. The level of the water is carefully marked during the test and subsidence after a period of one hour indicates a fault somewhere, but a slight allowance is necessary at the commencement of the test for loss by absorption in pipes.

The smoke test is applied by one of the numerous smoke testing machines now on the market, of which "The Eclipse" is perhaps the best. *Fig.* 59. It consists of a double action bellows and a copper clyinder in which the burning material is placed. The cylinder is surrounded by a square copper tank filled with water which acts as a seal

to render water-tight a deep copper cover which floats over the cylinder. A flexible tube made of special composition to withstand the heat of the burning material is connected to the outlet of the machine and the drain to be tested. The smoke is forced by the machine into the drains through a gully outside the house or an inlet ventilator or through a clay plug in an inspection chamber. All outlet ventilators from soil and other pipes are kept open at first till a constant discharge of smoke is observed from their open ends. They are then closed by plugs or wet clay and the smoke in the pipes is subject to pressure which assists in detecting flaws in the pipes and apparatus. Various things are used to burn in a smoke test machine of which the two best are thick brown paper soaked in creosote (specially manufactured) and "oiled waste."

Another convenient method of applying the smell test is by patent "drain testers" of which Kemp's is perhaps as good as any, *Fig.* 60. It is very easily applied. The cover of the box is removed and held firmly in one hand or secured to something. The "tester" is then lowered into a water closet pan or a gully, and washed quickly past the trap by a sudden flush of water from a pail. This discharges the contents, producing a large volume of smoke in the drain and a very strong odour. The string attached to the cap and spring of the tester is withdrawn after a short time from the trap to prove that the contents have been satisfactorily discharged.

Fig. 59

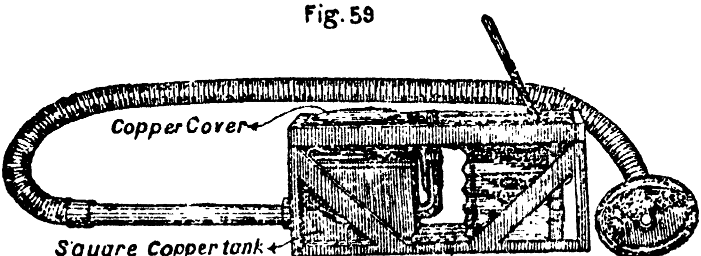
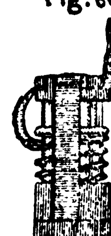


Fig. 60.



For small tests, the windows and doors of each room where there are pipes or connections to be tested should be kept carefully closed the whole time to facilitate the location of any defect that may be found. The person making the test should have a keen sense of smell and whenever he detects any smell in a room, he should, before trying another room, refresh the keenness of his sense of smell by inhaling in the open air.

60. **Construction of underground drains and methods of clearing obstructions.**—The construction of underground drains and the different methods adopted for keeping them clear of obstructions is fully described in the chapter on sewers and underground pipe drains, Chapter IV.

61. **Indian adaptations.**—The general principles of house drainage, as adopted in Europe, require some modification in their application to local conditions in crowded Indian towns. Underground pipe connections have generally been found unsuitable for the reasons explained in paragraph 3. The system now prevalent in India in Provincial towns and one that has given satisfaction so far in the absence of a water closet system is to construct open house drains of the pattern described in Chapter IV to carry all liquid sullage and house waste to the street drains, night soil being removed separately in conservancy carts. These drains are laid with a sharp fall, not less than 1 in 100, and are so arranged as to take in all the water used in the house for washing purposes to keep them flushed. They have the great advantage of being easily kept clean, and if any rubbish does collect in them they can only be obstructed by it temporarily. They are moreover, inexpensive as compared with underground drains, and this is a point of great importance in Provincial towns as a large percentage of the houses in them are of such a poor quality that they cannot afford the expenses of a water closet system or underground house drains. The funds available for sanitary works in such towns do not moreover permit in most cases of underground street drains all over the town. Sewers are only constructed in the main valley lines and all side streets are served by surface drains. The house drains, in such circumstances, must be of the open surface type for obvious reasons.

62. **Connection of open house drains with underground sewers.**—Where houses are situated on sewered streets and their drains are on the open system, the connection between them and the branch drain to the sewer should be made as shown in *Fig.* 61 below. This arrangement

Fig. 61.

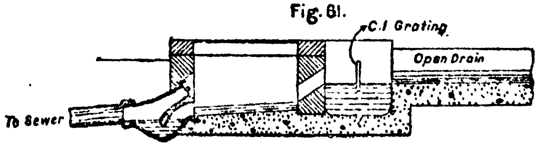
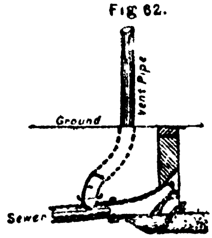


Fig 62.



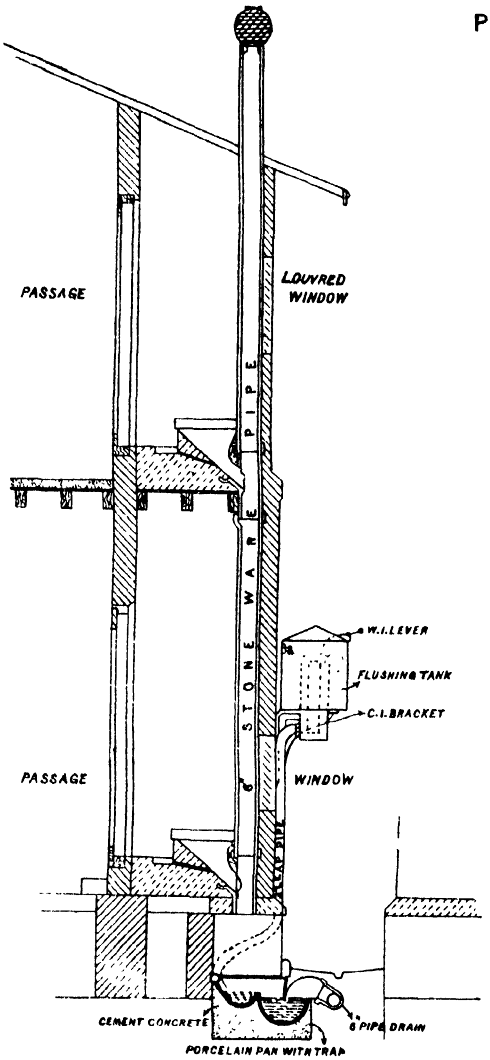
cuts off the house from all sewer gases generated in the closed sewer

by means of a disconnecting trap and provides at the same time a small silt pit with a grating for interception of all floating and solid matter which might block the drain pipe.

If the connecting pipe between the trap and sewer is of considerable length, a 4″ ventilating pipe should be fixed up the nearest corner or side of a house taking off from the pipe immediately below the disconnecting trap. See *Fig.* 62. The connecting pipe beyond the trap should be at least 6″ diameter and should be laid with a sharp fall.

63. **Construction of privies for large blocks of buildings where a moderate supply of flushing water is available.**—If new privies are to be constructed and a moderate supply of pipe water is available for flushing, the method illustrated in *Plate* IV, which is taken from "Oriental Drainage" by C. C. James, may be adopted for the better class of houses and for large blocks of buildings. By this method a glazed stoneware pan is substituted for the usual basket or pail at the bottom of the shaft, which holds some water, and receives the discharge from all the privies above it through a vertical 6″ pipe; an automatic flushing tank, set to go off periodically in the day time is fixed on the wall outside the privy which flushes out all the contents of the pan into a branch drain connected with the sewer. The flushing tank contains 10 gallons and is so arranged that it can also be discharged at will when only partly full. The soil pan is so shaped that heavy solid matter is retained in it and everything else is flushed away. The deposit in the pan is removed daily by a sweeper. This arrangement has been found to be satisfactory in Bombay and does away with the hand removal of faeces. The sloping surfaces under the seat which receive the night soil and deflect it into the soil pipe are lined in the better class of privies with plate glass, as this material is not corrodible and faecal matter does not readily cling to it and it is easily washed. The soil pipe is carried up full bore above the roof to act as a ventilator. As the soil pipe is not flushed out after each discharge, its cleanliness depends entirely on the water thrown down it occasionally by hand through the privies. This arrangement is an objectionable one from a sanitary point of view but it seems to be the best that could be devised when water closets were not possible and, as it falls in with the caste prejudices and habits of the people, they are said to prefer it to all other arrangements. It is certainly a great advance on the primitive methods in force at present in undrained Indian cities and is much less expensive than a regular water closet system. A ventilated passage should, if possible, cut off the privies from the rest of the building and there should be a louvred opening above the seats.

PLATE IV


PASSAGE
LOUVRED WINDOW
STONE WARE PIPE
6"
W.I. LEVER
FLUSHING TANK
C.I. BRACKET
PASSAGE
WINDOW
CEMENT CONCRETE
6 PIPE DRAIN
PORCELAIN PAN WITH TRAP

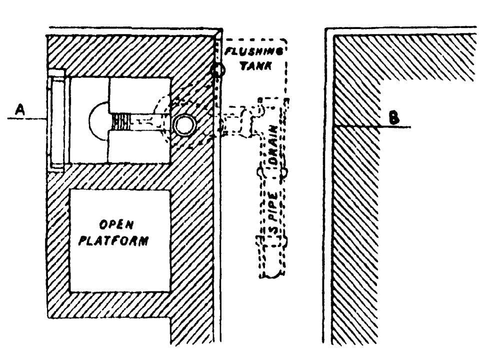

FLUSHING TANK
A
B
OPEN PLATFORM
PIPE DRAIN

Fig. 63.

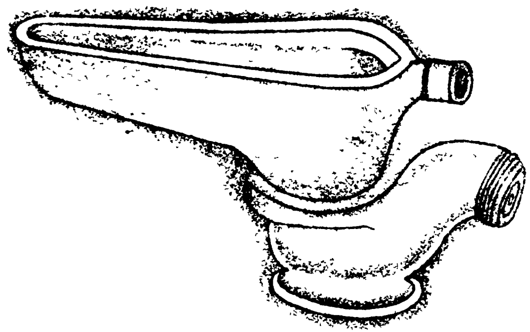


Fig. 64.

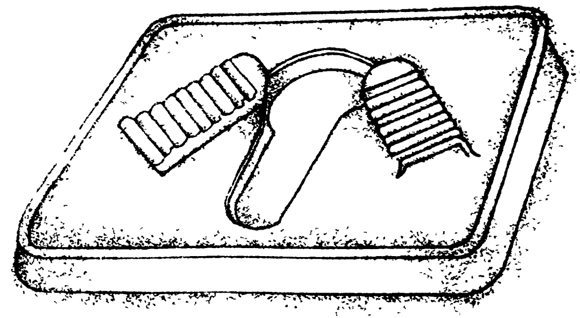
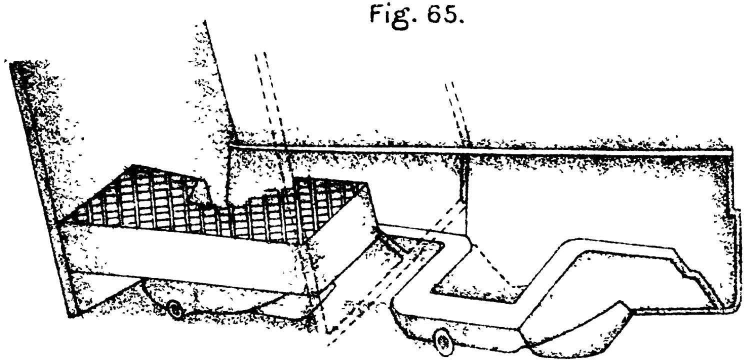


Fig. 65.



64. **Water closets and urinals adopted for the use of Indians.**—If water closets are required for high class residences of Indian gentlemen, their seats will probably have to be adapted to the Indian habit of sitting in a crouching attitude when using these conveniences *Figs.* 63 and 64 show a form of closet and foot plate suitable for this purpose, as manufactured by Messrs. Doulton and Company, Limited, of London. They are generally fixed so as to keep the top of the foot plate about six inches above floor level. *Fig.* 65 shows a pattern of water flushed urinal suitable for Indians as manufactured by the same firm. The trapping and ventilation arrangements for such apparatus should be exactly the same as those of water closets and urinals of the European pattern.

CHAPTER VI.

SEWAGE LIFTS.

65. Conditions which necessitate the use of sewage lifts.—When the available fall is insufficient to produce a self-cleansing velocity in the sewers it becomes necessary to adopt some form of lift to provide an artificial fall by raising the sewage at the outfall or at one or more points on its way thereto. When all the sewage can be dealt with at one point, a steam or oil engine is usually employed to raise the sewage in connection with ram pumps or centrifugal pumps as explained in para. 10, Chapter II, but when the features of the ground are such that lifts must be provided at several points on the site of the town to furnish the required slopes, one or other of the lifts described below has to be resorted to.

66. Shone's hydro-pneumatic system.—*Figs.* 66 and 67 are a section of a Shone Ejector, which consists of a cast iron container varying in size from 50 gallons capacity to 1,200 gallons according to the work to be done. The container is connected at the bottom on each side with an inlet and an outlet pipe and it has an arrangement at the top for the admission of compressed air from a reservoir which supplied the power for working it. The sewage from the low level sewer flows into the Ejector, E, through the inlet pipe, I. When the Ejector is full up to the lower edge of the bell, B, at the top, it encloses the air within it. The sewage continues to flow in and rises outside the bell, compressing the air in it until at last the pressure becomes sufficient to raise the bell and the spindle, S, attached to it, which actuates the valve, V, on the air accumulator pipe and admits compressed air into the Ejector, E. The compressed air thus admitted forces the sewage out of the Ejector through an opening at its bottom into the rising outlet pipe, O, through which it passes into the high level sewer. When the sewage surface level in the Ejector has fallen so low as to leave the full cup, C, unsupported, the cup descends by its own weight and pulls down the bell and spindle to their original position by its fall and closes the valve, V, allowing the charge of compressed air in the Ejector to escape at the same time. As soon as the pressure of air in the Ejector is relieved, the valve, F, at the bottom of the outlet pipe closes, and the valve, G, at the bottom of the inlet pipe opens, to admit a fresh charge of sewage into the empty Ejector to be in its turn forced out, when the whole operation is repeated.

67. The advantages claimed for this system are that its working parts are so simple that they are not likely to get out of order or be injured by

Fig 67

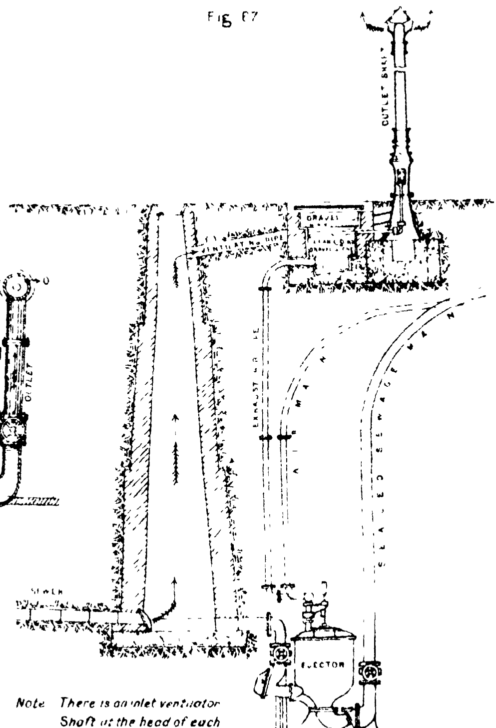
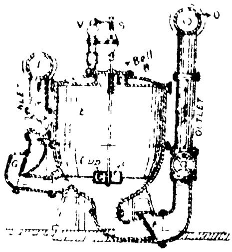


Fig 66



Note. There is an inlet ventilator Shaft at the head of each Sewer

No. 834 26

Fig. 68.

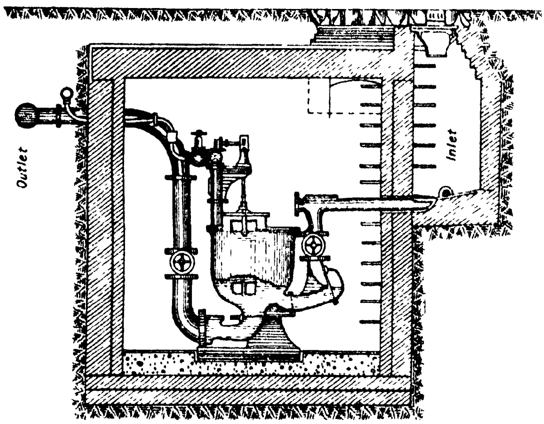
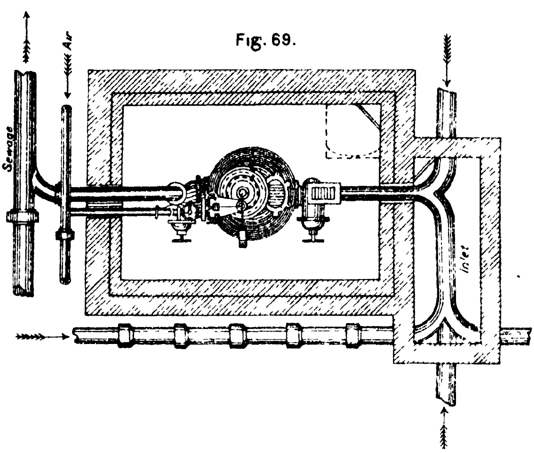


Fig. 69.



the sewage or grit; there is a free passage throughout for the solids in the sewage; the heaviest solids fall to the bottom of the Ejector and are the first to be forced into the outlet pipe; a copious flush of liquid is discharged into the upper sewer at each emptying of the Ejector which admits of smaller pipes being used than would otherwise be necessary. And last, but not least, as several Ejectors can be worked satisfactorily from one central air-compressing station, the system enables a town to be readily divided into several minor independent drainage districts with a common outfall. *Figs.* 68 and 69 show the arrangement of inlet and outlet pipes and the brick chamber in which the Ejectors are placed, and **Fig.* 67 is a diagram of the connections between the Ejector and the street sewer on one side and the sealed sewage or rising main on the other, as also of the ventilating arrangements.

In *Fig.* 67 the shaft nearest the Ejector is the ventilator into which the exhaust pipe discharges, each Ejector chamber being provided with a tall shaft of this description, 40 to 50 feet in height. The shaft on the street sewer side is an inlet shaft; one of these is usually placed at the head of each gravitating pipe sewer. This is the only ventilation the Shone system has and it is said to work very efficiently on the whole.

The air is compressed in the usual manner by means of direct acting steam engines of the compound or triple expansion type, the pistons of which are coupled direct to those of the air compressing cylinders, and it is stored for use, as required, in loaded accumulators.

68. From a purely hygienic point of view, this system is most satisfactory as it removes the sewage rapidly from the inhabited parts of the town to the Ejectors and from these to the outfall or outfalls and it has many engineering advantages, as above explained, but it is not altogether free from drawbacks in practical working. Its cost is comparatively high, and its mechanical efficiency as gauged by the useful lifting work done in proportion to the energy consumed by the compression plant is low. The cost is affected by the additional plant required in the shape of air compressing machinery, cast iron air mains and sealed sewage mains and the Ejectors with their adjuncts. The loss of efficiency is due to the impossibility of using the air expansively as in steam, the heating of the air during compression and the subsequent loss of pressure on cooling, the difficulty of preventing considerable leakage in air pressure mains and Ejector valves. In spite of these drawbacks, however, it may in some cases prove to be the most advantageous where a gravitation system is not possible. It has been adopted for several districts of Bombay city and

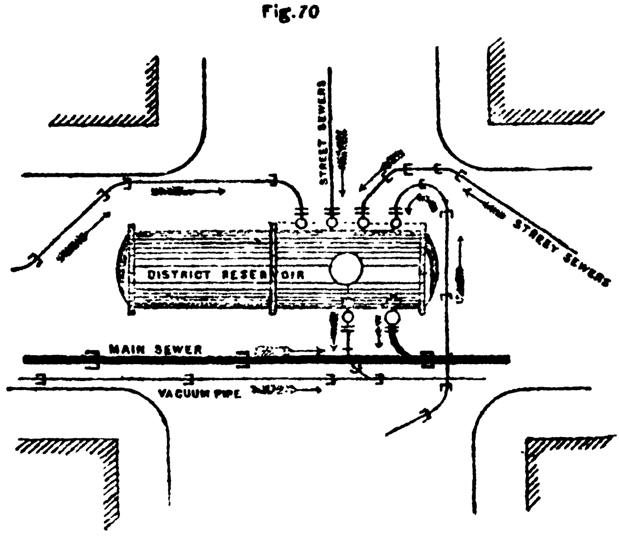
* "Oriental Drainage" by O. C. James.

for Rangoon and Karachi, where it is reported to be giving satisfaction. See the paper on Karachi Sewerage Works by Strachan, in Proceedings, I. C. E., Vol. 135. The English manufacturers are Messrs. Hughes and Lancaster, Engineering Works, Chester, and 16 Great George Street, Westminster, to whom enquiries should be addressed for prices or further information.

69. **Liernur vacuum system.**—This system was first introduced into Amsterdam in 1870 and has since been adopted by several other low lying towns on the Continent. It furnishes another method of meeting the difficulty of insufficient fall for the proper working of sewers, the difference between this and the Shone system being that the sewage is not lifted but sucked through air-tight pipes by creating a vacuum in a receiver. In this system the amount of liquids admitted to the sewer pipes is reduced to a minimum. It is intended for conveyance of faecal matter and household slops only.

The faecal matter and household slops are collected, after passing down the soil pipes, in a small cast iron siphon tank hermetically closed and placed below them. From each siphon tank, a cast iron branch takes off and joins a cast iron street sewer in the road. The town to be sewered is divided into a number of small districts, and, in the centre of each district a cast iron receiver is placed to which all the street sewers are connected. Every day, by operating valves, these district receivers are put in communication with the street sewers and under the pressure of the external air the faecal matter in the house tank siphons is carried into them. The

Fig. 70



district receivers are again joined by a system of outlet pipes called Collectors which lead the sewage to a central reservoir at the pumping station, situated preferably outside the town, which also contains the pumps required for producing a vacuum in the whole system—see *Fig.* 70.

70. An indispensable condition for the working of this system is the absolute air-tightness of the whole of the sewer net work as the motive power is atmospheric pressure. An advantage claimed for it is that pipes may follow the contour of the ground, no fall being necessary. The sewage of the whole town is said to be driven by this system in a few hours daily into the main reservoir, where it is treated with sulphuric acid to fix the ammonia. The resultant liquid is then evaporated and the solids are dried and sold as "Poudrette," which is stated to possess a high manurial value. The expense of installation and its low mechanical efficiency are against this system, as also the necessity for provision of two sets of sewers (one for faecal matter and one for sullage) in addition, in some cases, to separate provision for storm water. It does not appear to have met with approval in England and it would be particularly unsuitable for a hot country like India, as it involves the storage of putrefying matter in receptacles for the greater part of the day at the bottom of the soil pipes close to each house.

71. **Hydraulic.**—As in the Shone system, the power in this system is generated at a central station and transmitted through pipes to several automatic pumping stations in the town, each serving a small district round it. The power is generated by hydraulic ram pumps of the ordinary type, worked by steam or water wheels, which supply water under a pressure of 500 to 700 lbs. per sq. inch to a system of iron pipes leading to hydraulic engines in the various sub-stations. The pumps discharge into pressure pipes through a loaded accumulator at the central station, the rise and fall of which automatically admits steam to or cuts it off from the steam pumps by means of an equilibrium valve on the main steam pipe connected to a weight suspended directly over the accumulator. All that is necessary, therefore, to secure the automatic working of the whole system is to keep up the pressure of steam in the boilers at the power-house.

The first cost of this system is high for the same reasons as those which make the Shone system expensive, but it is claimed that its efficiency is higher than that of the Shone system as the temperature and leakage losses in the case of water under pressure are less than those of compressed air. On the other hand, it should be remembered that the

friction loss in the air mains is comparatively small and in hydraulic transmission the water used must be collected and stored before use, and, having actuated a motor, some means must be found for removing it, while air is every where available and can be discharged any where without causing trouble. Whether hydraulic or pneumatic transmission of power is the more economical in first cost and working expenses depends on various circumstances which must be determined in each case before a decision is arrived at as to which should be adopted.

72. Students requiring more detailed information on the subject of hydraulic and pneumatic transmission of power are referred to Professor Unwin's book on the "Development and Transmission of Power" published by Longman and Co.

73. **Adam's Automatic Sewage Lift.**—If only a small part of a town site lies so low that it cannot be brought into the general scheme of drainage, this method is very useful for securing the required fall for the low area by lifting the sewage from a low level sewer to a higher level either by the descent of water, from a high level tank which is filled with water, as required, from the water mains of the town, or, by power generated by the descent of some of the sewage intercepted from one of the high level sewers. It works on the principle that the fall of water or sewage from a high level to an intermediate level can be utilized by means of a suitable arrangement of pipes and cylinders to raise a corresponding volume of sewage from a low level sewer to a sewer at the intermediate level, if the difference between the high and intermediate levels is sufficiently greater than that between the intermediate and low to overcome the friction losses of head in the pipes and cylinders. A diagram of the arrangement is given on *Plate* V.

The action of the lift is as follows. The low level sewage to be lifted flows through the inlet chamber into the forcing cylinder, A. When this is full the sewage heads up in the inlet chamber and raises the float, B, which opens the cock, C, on the water supply pipe. The water is thus laid on to the automatic flushing tank, D. When the tank is full, it discharges by siphonic action through the fall pipe into the air cylinder, E, whence the air is displaced through the air pipe, F, connected with the forcing cylinder, A. The sewage in A is thus put under air pressure and is forced up into the sewer at the higher level, G. When this forcing action is over, sewage begins again to flow into A, and the float, B, descends and shuts off the water supply to the flushing tank. Meanwhile, the water which has filled cylinder, E, and has risen in the pipe, H, is siphoned out by that

ADAMS' PATENT SEWAGE LIFT.

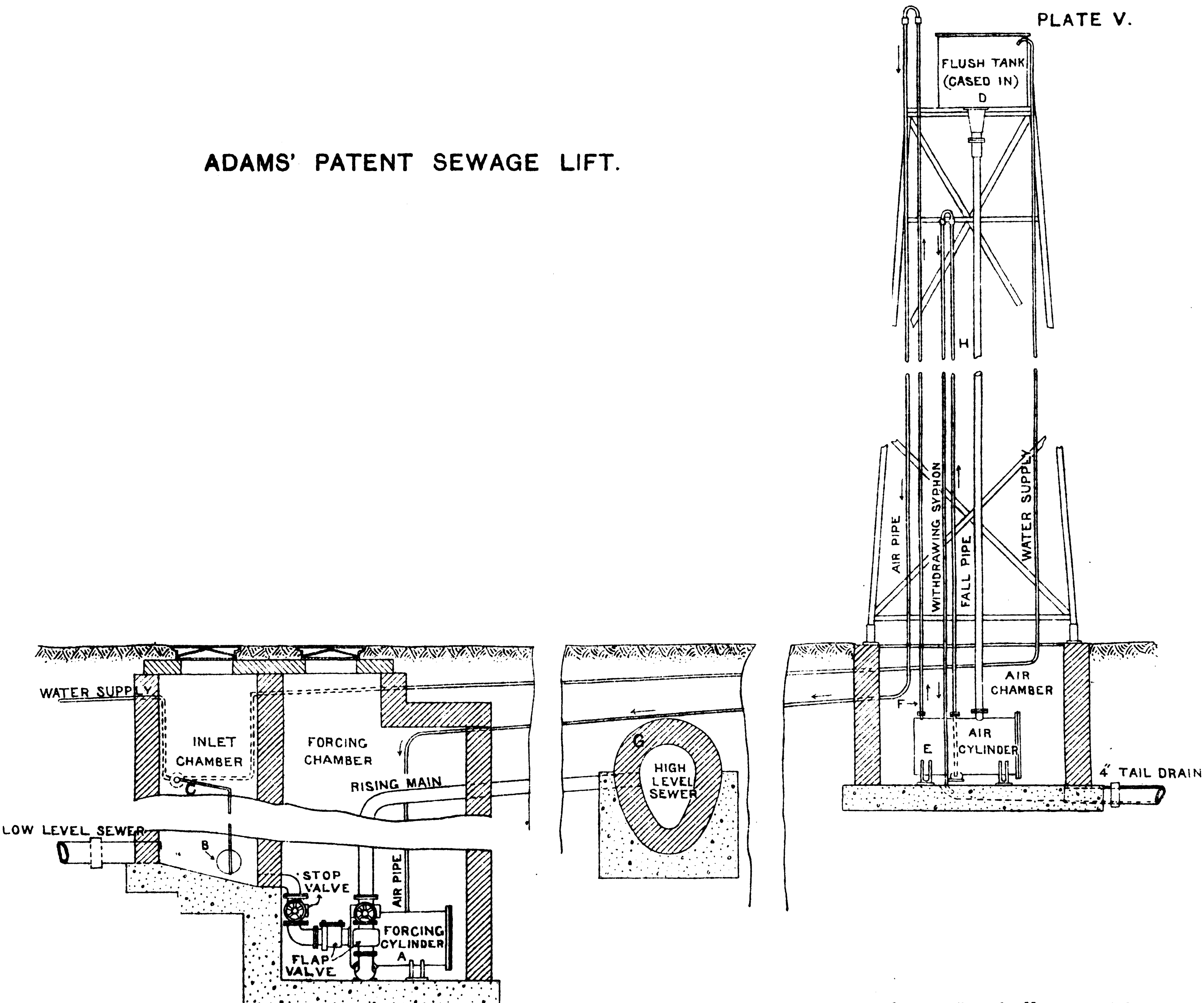


Photo. Zinco, April, 1926.—No. 834-20=400

pipe and runs either to waste or to any place where clean water may be required. On the cylinder, A, again becoming full, the above described action again takes place. The air pipe, F, and siphoning pipe, H, are carried up to a high level, the one to prevent water being carried over, and the other so that the water may not be siphoned out of E till it is overcharged, the contents of the flushing tank being slightly in excess of the capacity of the cylinder E.

74. The system described above is the simplest form of Adam's Sewage Lift worked by a water supply. When sewage is to be lifted to an intermediate level drain by means of the sewage from a high level drain instead of by water, the arrangement would be on the same lines, but, in this case, it would be necessary to observe a proper relation in the volumes of the high and low level sewage and the differences between high and intermediate levels and intermediate and low levels.

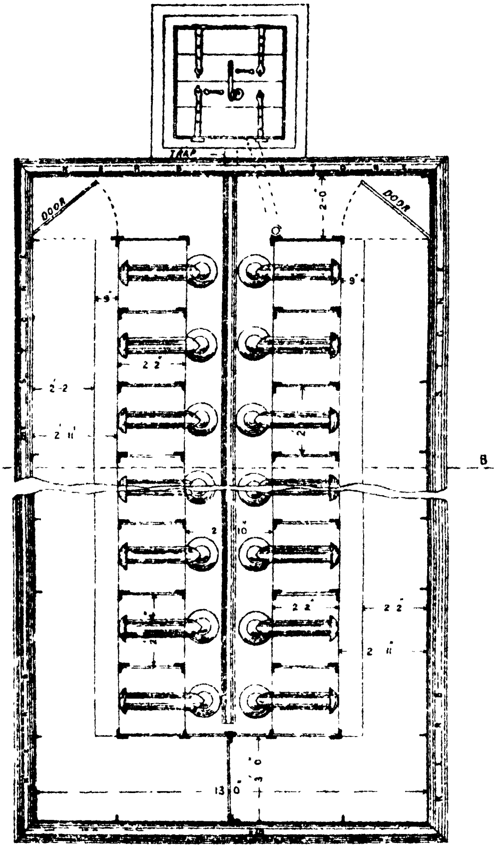
75. A full description of this lift will be found in Vol. CLX of the Proceedings of the Institution of Civil Engineers.

76. **Electrical system.**—The use of electricity for raising sewage has only recently been adopted by Sanitary Engineers. In towns which have electric light and electric trams, it would obviously be both desirable and economical to make use of the power available from these undertakings for lifting sewage, as it would furnish a very useful day load and tend to improve the load factor of the electric installation. Where water power is available all the year round at a convenient distance from the town site, it may be economical, in some cases, to instal turbines and dynamos at the source of power and to transmit the current by cable to electric motors and pumps at one or more points in the town or at the outfall where sewage has to be lifted. The pumps in such installations are either of the centrifugal type or 3 throw ram pumps driven through worm gearing running on ball bearings. The motors are sometimes arranged to work automatically by the use of switches operated by floats controlled by the level of the sewage in a sump adjoining the pumping station. In an installation which gets its power from an electric light plant, it is necessary to draw off the current very slowly for the pump motors to prevent any greater fluctuation likely to affect appreciably the electric lights on the circuit, and for this purpose an arrangement consisting of a dashpot with a multiple contact automatic switch has been used by which the starting current is gradually turned on, the movement occupying 5 to 10 seconds.

The motors and pumps are generally placed in a small chamber beneath the roadway and the absence of steam or oil engines in an installation of

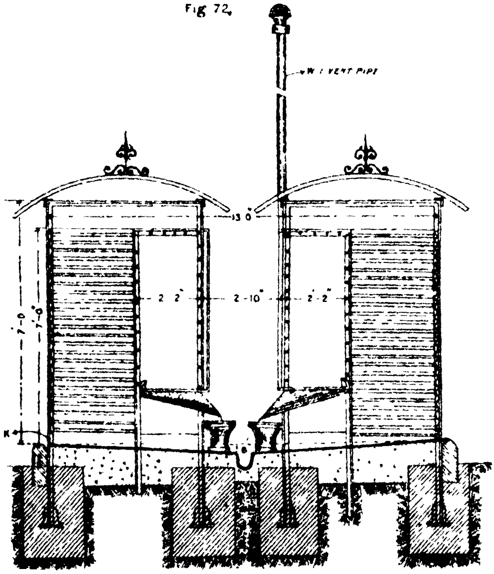
this description enables the station to be kept scrupulously clean. Where they had been tried, such installations have given complete satisfaction, having been found to be both economical and sanitary.

Fig. 71



PLAN

Fig 72.



CHAPTER VII.

PUBLIC CONVENIENCES.

77. As Sanitary Engineers in India are often required to design public conveniences for municipalities, this Manual would not, the author thinks, be complete without a short chapter on the methods of construction employed for such works.

It is very desirable that all large Indian towns should bé supplied with public latrines and urinals, as apart from the convenience to the residents of having these at important centres, their absences is almost certain to lead to the fouling of roadside drains and odd corners which in a tropical climate soon become offensive. The drawings of the conveniences described below represent the latest approved patterns adopted in Bombay. They have been taken from "Oriental Drainage" by C. C. James.

78. **Dry Pattern Latrines.**—*Figs.* 71 and 72 show a range of what are called in Bombay, Crawford System Latrines; these can only be used in secluded places for the poorer class of people. The solid and fluid night soil is collected in the same bucket, the contents of which are emptied into conservancy carts and carried away once or twice daily. There is no connection with any cesspool or sewer. The sloping shoot is usually constructed of wrought iron and is cleaned daily by the attendant in charge. The shoots, as well as the receptacles, are well tarred from time to time to deodorise and disinfect them. This latrine can be economically constructed with a cement concrete floor, the superstructure being of light angle iron standards with the roof and walls of corrugated or plain sheet iron. Another type of dry latrine which has lately been much used in India is the Horbury pattern, particulars of which can be obtained from Messrs. Richardson and Cruddas of Bombay.

A convenient method of construction for such latrines is to place them in two rows back to back, those for men being on one side and those for females on the other, with a paved passage between for cleaning purposes.

79. **Latrines on the Water Carriage System.**—If the town has a good water supply under pressure and an underground drainage system, public latrines should, as far as possible, be on the water carriage principle as these are much more sanitary in every respect. In earlier time cast iron pans were used for such latrines, but manufacturers have recently been able to turn out porcelain or glazed stoneware pans of a design which is quite suitable for the natives of India and can be kept much cleaner

than the old cast iron variety. *Figs.** 73 to 75 show a good latrine of this type. If sufficient funds are available, the inside of each compartment should be lined to a height of 3 feet with white glazed tiles. The seats are in two rows back to back for males and females, with a passage between. Each seat is provided with a three gallon automatic flushing tank fixed on brackets at such a height as to be beyond interference. The soil pan is flushed from the front and also from a flushing rim which surrounds the top of the pan. Foot rests are formed on the pan in the proper positions for Indian users to squat on. The contents are flushed through an ordinary trap direct into the pipe drain.

A paved and drained washing platform is necessary in Indian latrines, the water supply being laid on with a half inch pipe and an ordinary brass plug tap. The drainage is led away through a trapped gully into the sewer pipe serving the latrines.

80. Trough Latrines.— A latrine of this pattern will sometimes be found more advantageous than those described above when it is required to accommodate large numbers of people. It is particularly suitable for mills and factories. The latrine is cheaply constructed of corrugated iron or masonry. *Figs.* 76 to 78 show a form of latrine of this type which has been found to be very satisfactory in Bombay. The trough always holds up 6 inches of water and is automatically flushed from a 50 gallon flushing tank every hour or two, which is so arranged that it can also be operated at will at any time, if necessary. The pan is similar to that of the water carriage latrine described above but the lower half is cut away as no trap is required. To avoid splashing, which is naturally objected to by users, a small iron plate is suspended under each pan just below the normal level of the water in the trough which is cleared every time the flushing tank is discharged. These latrines are simple and inexpensive and are perhaps the best that can be provided for the poor and uneducated classes.

81. **Urinals** —*Figs.* 79 to 81 show a type of public urinal for natives which is said to have given great satisfaction. It was designed for Bombay by Mr. C. C. James, Drainage Engineer, and Colonel T. S Weir, I.M.S., Health Officer. The trough is of white porcelain and the front is lined with glazed tiles to a height of 3 feet 6 inches up to the copper flushing pipe. The partitions are marble slabs 6 feet in height and 2′ 3″ apart. The urinal is flushed continuously with a constant dribble of water through a perforated copper pipe from a tank placed on top as shown in the drawing. As an alternative, a small automatic flushing tank might be provided to go off every hour or so and flush all the divisions together. With an

* "Sanitary Engineering," by Vernon Harcourt.

Fig. 73.

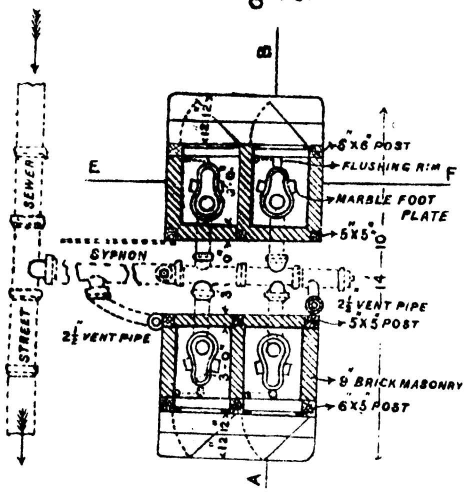


Fig. 74.

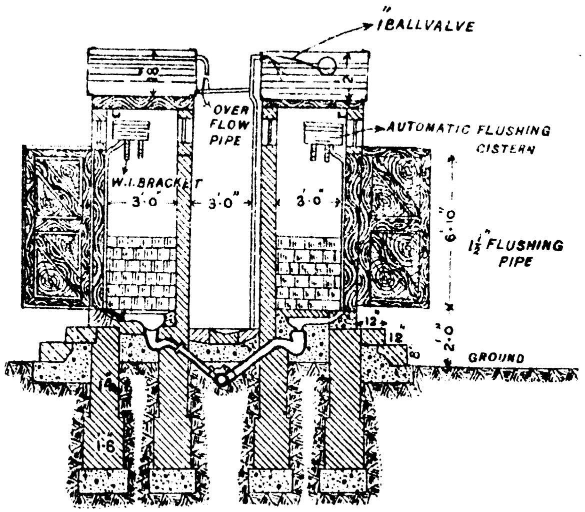


Fig. 75.

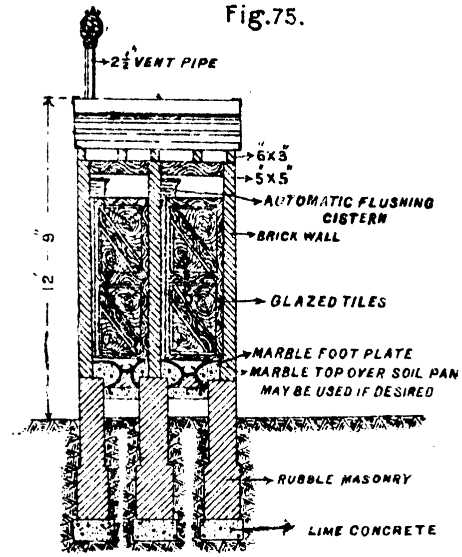


Fig. 76.

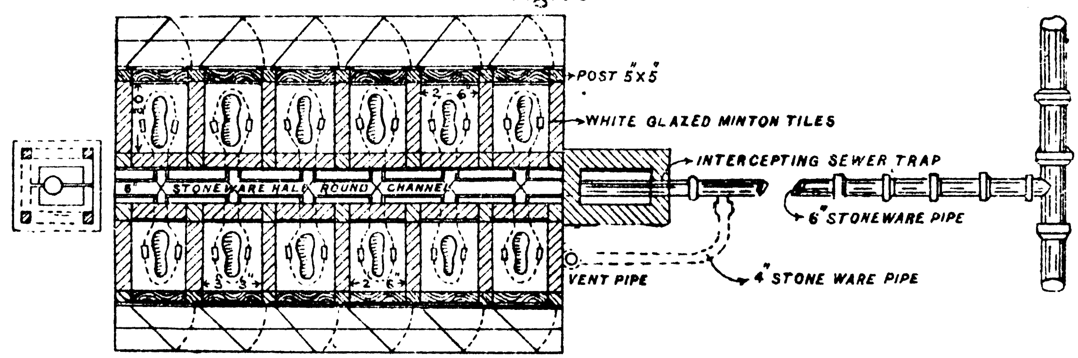
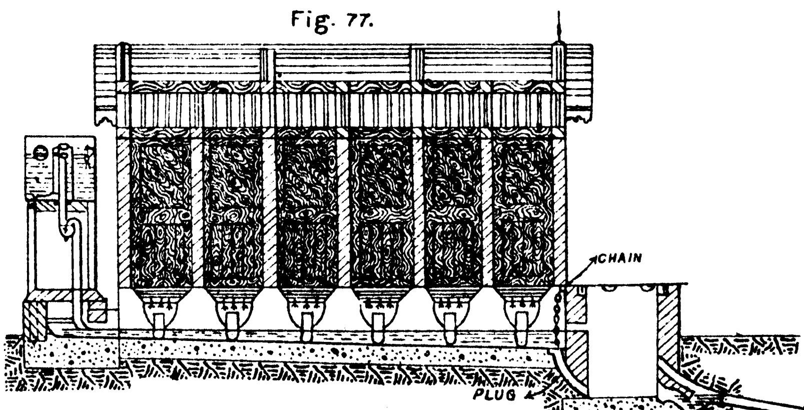


Fig. 77.



LONGITUDINAL SECTION.

Fig. 78.

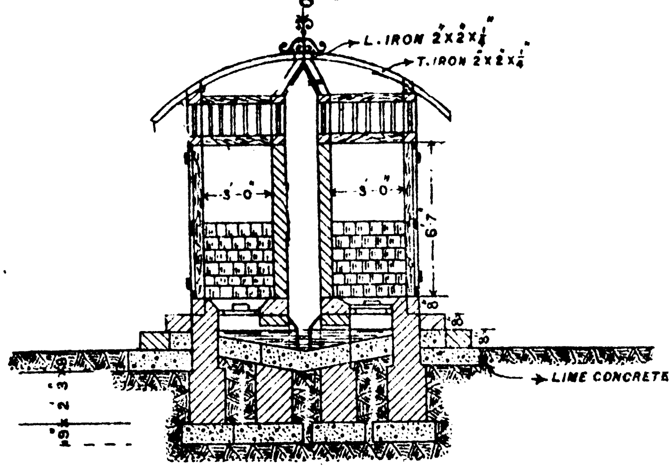
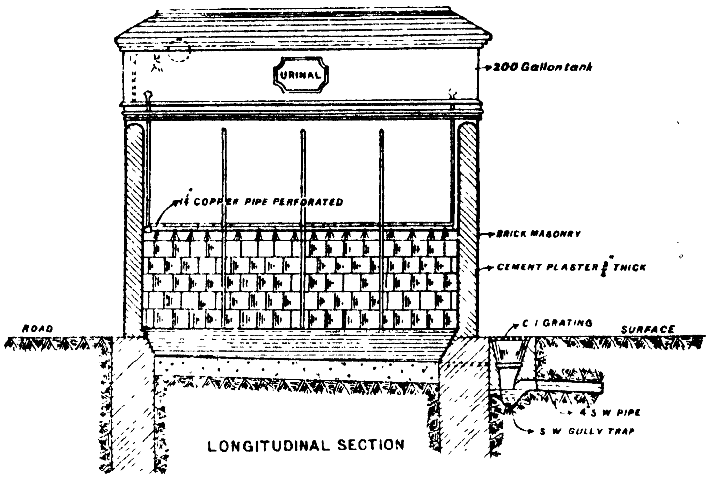
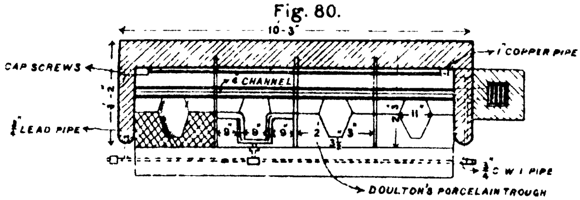


Fig. 79.



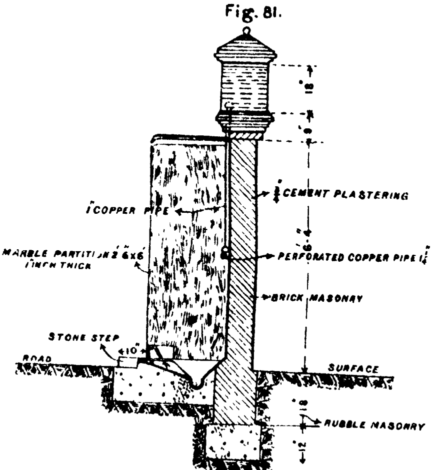
LONGITUDINAL SECTION

Fig. 80.



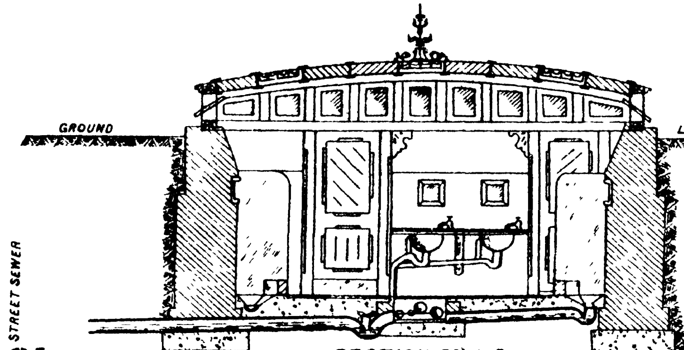
PLAN.

Fig. 81.

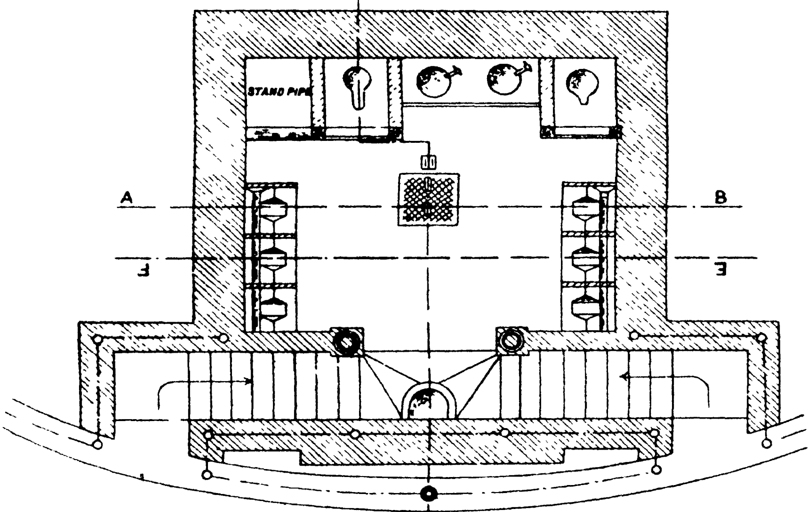


CROSS SECTION

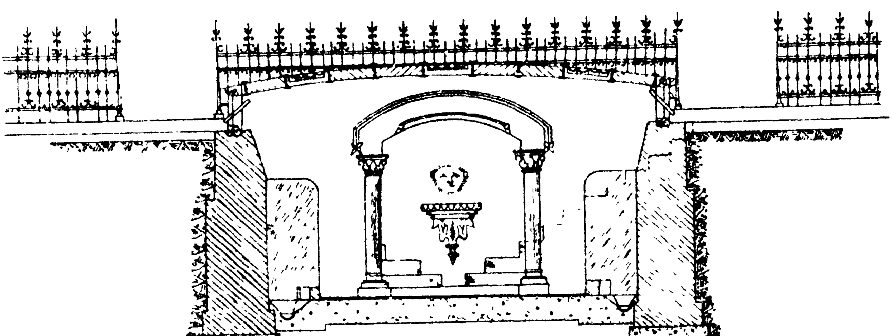
PLATE VI.



SECTION ON A.B.



PLAN



SECTION ON E F.

Photo. Zinco. August, 1926.—No.834-21

automatic arrangement, a central vertical pipe comes down a short distance from the bottom of the tank against the wall and branches off on both sides giving off a branch over each division with a splayed rose at the end to spread the flush water over the face of the glazed tiles in front on its way to the trough. The contents of the trough discharge through a gully trap at the lower end connected with a sewer. A latrine of this pattern is equally suitable for use in a standing or squatting position. The front tiles and trough have to be cleaned occasionally with a dilute solution of sulphuric acid to remove stains which discolour the glazed surfaces after a time.

82. **Underground Conveniences.**—These may be useful sometimes in large towns at important centres of traffic where public latrines above ground are not possible. They can only be constructed in places where there is an underground sewerage system at a sufficient depth and a plentiful supply of water for flushing. Such conveniences are now commonly used in English towns but they have not been adopted in India to the same extent because the heat in summer is likely to make them smell badly if they are not well ventilated and kept scrupulously clean. Ample ventilation through openings under the roof above ground is absolutely essential and in the hot plains of India it would probably be further necessary to extract the air in some way either by fans or shafts topped with revolving cowls. Plate VI shows a design for a convenience of this kind erected recently at Bombay. It includes six urinals, two washing basins, one European water closet, one water closet for natives and an ablution platform with a water tap. The room is lighted by Hayward's glass pavement lights inserted in the roof. Entrance and exit steps are provided on one side, and there is an ornamental drinking fountain at the bottom of the stairs. The whole installation is complete for both Europeans and natives.

CHAPTER VIII.

SEWAGE DISPOSAL.

83. **Selection of a site for an outfall.**—The site for a free outfall into the sea or a river should be selected with the greatest care to prevent the possibility of the sewage becoming a nuisance in the neighbourhood of its outlet, or, if discharged into tidal water on the ebb, of being partially brought back by the succeeding flood tide.

Crude sewage from a town should never be discharged into a fresh water river unless the latter is large enough to afford rapid and ample dilution and there are no towns for several miles below.

In tidal rivers, it is well known that floating matters are carried down and up a river for several tides before they are finally taken out to sea, if the fresh water coming down bears but a small proportion to the tidal water brought in by the flood tide and a strong wind is blowing up-stream. It is the usual practice to discharge sewage, which floats on the surface, into a tidal river directly the ebb current or return tidal flow sets in but as the discharge at the outfall must take some time, the sewage let out towards the end of the discharging period is sometimes carried back by a succeeding flood tide higher up the river than the outfall under unfavourable conditions.

Even when the outfall is into a large estuary or the open sea, it is necessary to ascertain by floats the set of the currents along the coast as also the direction and force of the strongest winds in the locality, for a very strong wind has been known occasionally to reverse at the surface the direction of the current running fairly strongly lower down. When a suitable site has been selected for the outfall, with due regard to the above considerations, the discharge should take place beyond low water of spring tides and only during the period of the ebb most favourable for the complete removal of the sewage.

If local conditions are not favourable for a free outfall of sewage into a river or the sea it will be necessary to clarify it to some extent by settlement or precipitation or to purify it by one or other of the methods described below before discharging it at the outlet.

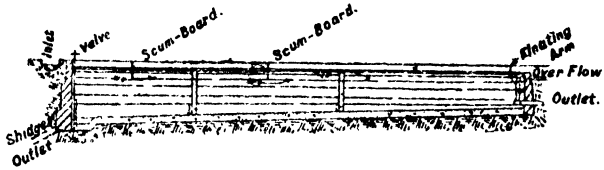
84. **Clarification of Sewage.**—A great reduction can be effected in the impurities of sewage by the previous removal of the solid constituents by settlement or precipitation but the objections to this process are that it involves considerable expense and it is difficult to get rid of the resulting deposit of sludge without causing a nuisance. Sedimentation

alone is often not sufficient, as the suspended matters in sewage are light and cannot be separated in a reasonable time by settlement, so it is necessary to resort to chemicals for rapid precipitation. Lime in solution is commonly used for this purpose at the rate of 3 to 5 grains per gallon. The exact amount to be added must be determined by experiment in each case as it varies with the composition of the sewage. It should be just sufficient in quantity to effect the precipitation and no more, for an excess is prejudicial to the subsequent action of bacteria in purifying the effluent and tends to increase the quantity of putrefying matter in solution. The addition of some aluminium sulphate or ferrous sulphate in the proportion of 1 to 4 has been found to improve the precipitating efficiency of lime.

Many other processes of clarification have been brought forward from time to time, among which may be mentioned the A. B. C. and the Ferrozone, but the lime process is simple and economical and is still in favour with Sanitary Engineers. All these processes, however, can only be regarded as producing a more or less satisfactory *clarification* of the sewage; no chemical treatment of sewage hitherto proposed has, by itself, succeeded in producing a properly purified effluent. Clarification, when resorted to, is only a preliminary operation to the purification of an effluent by dilution in river or sea water, by land irrigation, or by bacterial treatment.

For the settling and precipitation of the solids, the sewage after it has been mixed with the proper proportion of precipitant, is led into long rectangular tanks of brick work or concrete, lined inside with cement plaster, the floors of which slope upwards from the inlet to the outlet. The sewage is made to flow slowly along the tank by means of cross walls and scum boards, which give it a devious course and keep it in due circulation throughout the tank. See *Fig.** 82.

Fig 82.

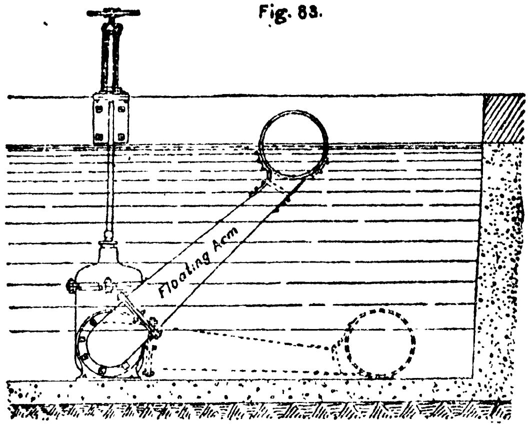


When a sufficient quantity of sludge has collected at the bottom, the liquid is drawn off at the outlet through a hinged pipe with a floating arm which keeps its orifice always a little below the surface to exclude the scum

* "Sanitary Engineering" by Vernon Harcourt.

floating on top. *Fig.* 83. When all the liquid has been drained off to

Fig. 83.



outlet level, the sludge is either run out through a pipe at the inlet end of the floor or, if the tank is underground, sucked or pumped up to ground level.

Clarification by sedimentation or chemical precipitation will only be useful as a rule where the sewage contains night soil and a large proportion of putrescible solid matter. It will hardly be necessary for the sullage of towns in Upper India from which night soil is excluded.

If the sewage is not charged with solids to such an extent as to require clarification, it will be sufficient as a rule to pass it successively through a set of strainers consisting of two or three gratings of diminishing mesh.

The sludge removed periodically from the tanks is either deposited on drying beds, to drain and dry, and then trenched into land, or it is compressed by a pressing machine into sludge cake which is sold as manure. The former is the more suitable method for India.

85. Experiments recently made in England go to show that it is possible, by centrifugal action in rotary machines called "centrifuges," to separate a large proportion of the water in sludge which is usually composed of 5 to 10 per cent. of solids and 90 to 95 per cent. of water. This has the effect of reducing very considerably the volume of sludge to be dealt with and, by rendering it comparatively dry and inoffensive, it removes to a great extent the difficulty of disposing of it without nuisance. This process is still under trial and has not yet been adopted by any municipality on a large scale as far as the author is aware.

86. **Electrolysis.**—Though not well suited for large volumes of sewage in India owing to their high cost, the electrolytic processes of deodorizing

and disinfecting sewage which have recently been introduced in England are briefly mentioned here for the information of students. By passing an electric current through sewage, the water and chloride salts in it are broken up with the liberation of oxygen and chlorine at the positive pole in a nascent state. These gases exercise a powerful deodorizing effect on the sewage. Iron plates are used as electrodes between which the sewage is made to flow and the iron salts produced by electrolysis precipitate the solids of the sewage. There is always some risk in this process of a considerable portion of the sewage passing between the plates without undergoing purification.

By another process (Hermite) an electric current is passed through sea water or a solution of magnesium and sodium chlorides, decomposing the magnesium chloride into magnesium hydrate and hypochlorous acid. The former is precipitated; the latter, a liquid, acts as a strong disinfectant and deodorizer and is used by being poured into the sewage at the head of the sewer or into flushing cisterns or water closets and drains. This process has recently been developed on a larger scale by the design of a special apparatus for effecting electrolysis with a large electrical area. The liquid produced has been employed with satisfactory results. This later process is known as the oxychloride system of purification. It has been patented by the Oxychloride Company.

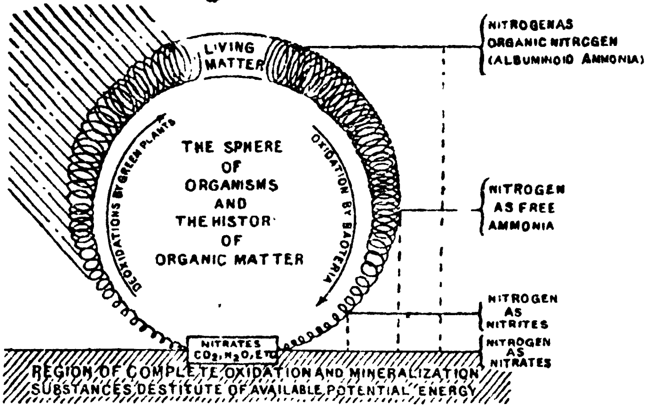
87. **Methods to be adopted where a free outfall to a river or sea is not feasible.**—Where a free outfall to a river or the sea is not feasible, the sewage must be disposed of either by the irrigation of a sewage farm or by bacterial treatment.

88. Irrigation of land is, on the whole, the simplest and most suitable method of sewage disposal as it returns to the land as manure the substances which have been derived from it. It is practically a combined method of purification and utilization. Under certain conditions it may, with proper management, prove a source of profit but this should not be regarded as the main object of adopting this method of treatment. In most cases, sewage farms must be regarded as merely the cheapest means available for the disposal of the sewage under certain conditions without creating a nuisance. The impediments in the way of the adoption of this method of disposal are (1) the large area of land required which in the vicinity of a town may be very expensive. (2) The difficulty in some places of procuring land of a suitable character and of sufficient extent. (3) The sentimental objections sometimes raised against a sewage farm in the neighbourhood of a town.

Irrigation of land may be considered a bacterial method of purification in some respects, whether conducted as "broad irrigation" on a large area of close soil, or by "intermittent irrigation" on a smaller under-drained area of porous soil. The purification is effected by bacterial agency in both cases and intermittent irrigation is only bacterial downward filtration on a large scale, effected in a more natural manner.

89. Where suitable land for a sewage farm is not available at a reasonable cost, there is no alternative but that of bacterial purification in works specially designed to suit the conditions of each particular case. Before describing the various methods by which sewage can be purified on biological principles, the Author thinks it would be useful to explain briefly to students the *rationale* of this system of treatment. Till quite recently, it was believed that dead organic matter was reduced to its elements by chemical decomposition entirely, but the science of biology now tells us that it is really converted into mineral matter by the digestive action of countless thousands of living creatures in the form of microscopic infusoria, worms, and bacteria. In this connection Dr. Duclaux wrote as follows in 1884: "Whenever and wherever there is decomposition of organic matter, whether it be the case of a herb or an oak, of a worm or a whale the work is exclusively done by infinitely small organisms. They are the important, almost the only, agents of universal hygiene; they clear away, more quickly than the dogs of Constantinople or the wild beasts of the desert, the remains of all that has had life." But this destruction is only a preliminary preparation for utilizing the components in the creation of new forms, destruction and creation going on continuously in cycles which are well illustrated by the following diagram, *Fig.* 84, by Professor Sedgwick indicating the changes by which inorganic substances of the soil pass through vegetables into living tissue by a process of deoxidation in the presence of sunlight, and thence, by oxidation to inorganic matter again. The increasing size and density of the spiral on the left shows the progressive complexity of organic matter as built up by the chlorophyll bodies of green plants in the sunlight, while the right half of the figure illustrates the reverse process carried out largely by bacteria. There are many "short circuits" in nature, as, for instance, when the dead organic matter of animals and vegetables is utilized by other organisms as food and built up into living tissue again without going through the whole round of nitrification and subsequent construction by the chlorophyll of green plants, but the complete cycle is as shown on the diagram.

Fig. 84



90. The recent methods adopted for the purification of sewage by biological treatment have for their object the rapid decomposition of sewage by bacterial agency by subjecting it to conditions favourable to their growth for periods necessary for the completion of the changes.

It is believed that two distinct species of bacteria produce the changes necessary for purification :—viz. Anaerobic bacteria, which flourish best in the dark without air, and Aerobic bacteria which require the oxygen of the air for the performance of their functions. The former cause putrefaction and liquefy the solids, giving out objectionable gases in the process; the latter, using the oxygen of the air, produce nitrification without the emission of any offensive odour. The biological works required for carrying out these processes are those noted below, which are described in detail in succeeding paragraphs.

For Anaerobic Treatment.

1. Septic or liquefying tanks.
2. Upward filtration beds (lower layers).

For Aerobic Treatment.

1. Contact filter beds.
2. Continuous trickling beds.
3. Intermittent sand filtration.
4. Upward filtration beds (upper layers and nitrifying trays).

91. It is now urged by some that the anaerobic treatment, which is always more or less offensive may be dispensed with and that the crude sewage may be purified by aerobic organisms alone in primary and secondary resting contact beds. This contention is apparently

entitled to considerable weight as there are now several installations of contact beds giving good results in which aerobic organisms only appear to effect the whole of the process. Contact beds are fully described in the following paragraphs.

92. **Irrigation of land.**—Where land of sufficient area is difficult to obtain in a suitable position or is very expensive, the sewage is first clarified in sedimentation or precipitation tanks before it is distributed over a sewage farm. This preliminary treatment tends to reduce the area required for purification and renders the land much less liable to be choked with a coating of slime; on the other hand, it removes some of the constituents which are valuable for manure and for producing bacterial changes and it necessitates special measures for the disposal of the precipitated sludge. If the sewage is not very strong and plenty of good land is available, it is advisable in most cases, to apply the sewage directly to the land, with or without straining, and this has been done successfully in several towns in India. In this connection, the extract in Appendix B from Dr. Gilbert Fowler's Report, dated 1909, on the treatment of sullage in the United Provinces will be found most instructive.

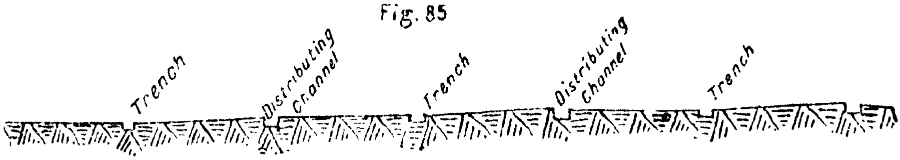
The above arguments apply, *mutatis mutandis,* to the method sometimes adopted of passing sewage through an anaerobic treatment in septic tanks before passing it on to a farm.

Any land can, to a greater or less extent, be made suitable for sewage irrigation, if a sufficient area is available, but stiff clay and marshy ground are the worst, and porous, loamy soil with an open subsoil is the best for the purpose. Rocky ground is, of course, altogether unsuitable.

93. **Broad Irrigation.**—Where an ample area is available at a reasonable cost, distribution of the raw sewage over the surface of the ground, known as broad irrigation, is usually adopted. By this system all the valuable constituents originally taken from the earth to form organic matter are restored to it and serve to manure it, while the purified effluent, if any, is eventually discharged into the nearest water course or drainage channel. In flat ground, the surface is laid out in long beds with slightly raised parallel ridges, about 40 feet apart, and shallow drainage depressions between them. On the ridges, the supply carriers formed of stoneware, brickwork or concrete are placed from which the sewage is diverted to the beds at suitable points by stop boards or iron plates introduced into transverse grooves in the carriers to arrest the current and cause an overflow on each side. See *Fig.* 85. From the supply carriers, the sewage gradually passes down the flat slopes of the beds and irrigates the soil, any excess finding its way into the intermediate

open drainage lines from which it flows to the outlet water-course or irrigates more land lower down. The supply carriers are fed at their heads from a main carrier, which is laid along the highest part of the farm to convey the sewage to them from the settling tanks or sewer outfall. They are similar in construction to the supply carrier, but larger. If funds are limited, the main carriers only might be constructed of concrete or stoneware, the supply carriers being earthen channels formed by a spade. *Fig.* 87 shows a plan of a small plot of sewage farm laid out as above described.

Fig. 85



Where the land has a considerable slope exceeding 1 in 60, a series of contour channels, like catchwater drains on a hillside, are formed at intervals down the slope, which successively intercept the sewage on its downward course and distribute it by overflow to the sloping bed below See *Fig.* 86.

Fig. 86

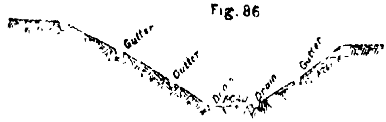
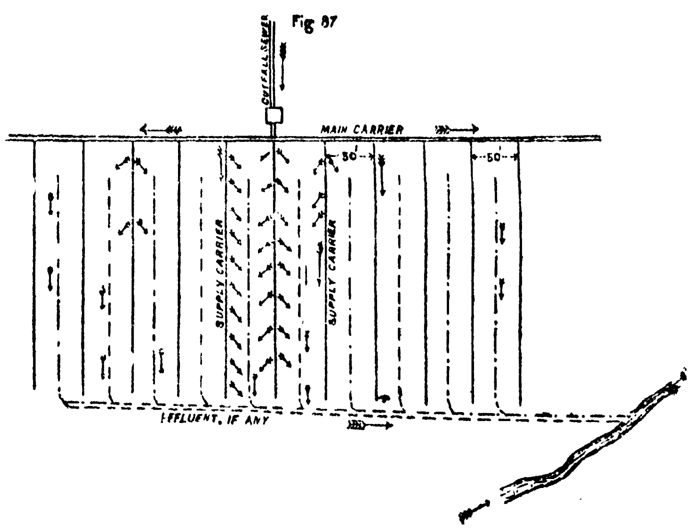


Fig 87



The slope of supply carriers should be about 1 in 400, and the main carriers, if large, might be flatter, up to 1 in 800. Any fall required in excess of this should be given by vertical steps.

94. To prevent the clogging of the surface of irrigated land by deposit of slime and sludge which would obstruct aeration and probably cause a nuisance where crude sewage is freely applied, the beds should be allowed periods of rest for the requisite chemical changes and the surface should be broken up and ploughed periodically. It may sometimes happen in dry periods that the crops turn yellow and show signs of unhealthiness from an overdose of strong sullage or sewage. When this occurs, it is advisable to give them one or two waterings with fresh water. It is useful to have a few special cheap irrigation wells on a farm for supplying fresh water for this purpose when required.

95. The quantity of sewage that can be applied to land depends almost entirely on the nature of the soil and the dilution of the sewage. The average daily volume of sewage distributed over the land per acre at Berlin and Paris is 3,000 gallons and 10,000 gallons per acre, respectively, while at Bombay Mr. James in his book on "Oriental Drainage" informs us that porous soil, under advantageous circumstances, will dispose of 30,000 gallons of sewage per acre per day, and heavy clay soil will only take about 5,000 gallons per acre. The sewage of Bombay is presumably weaker than that of Paris or Berlin. The hotter and drier climate of Bombay is also no doubt responsible in some measure for the difference in rates. In this connection see Appendices B and C. If preliminary treatment is resorted to, the rate per acre can be considerably increased. The following extract from paragraph 195 of the Fifth Report of the Royal Commission on sewage disposal (1908) is worth noting :—"Generally speaking the evidence points to a maximum rate of 30,000 gallons per acre, or 1,000 persons per acre with the best land after preliminary treatment, although some witnesses put the rate as high as 60,000 gallons or 2,000 persons per acre under similar conditions. With unsuitable land, such as clay, not more than 3,000 gallons per acre can be efficiently treated, even after settlement of the sewage."

96. In India, where no irrigation of crops is possible for a time during the heavy showers of the monsoon season, it is always advisable to provide a sufficient reserve of land under grass to take the sewage when it would be detrimental to valuable crops. The rivers and drainage channels at this time of the year are often so swollen with flood water that it may sometimes be permissible to turn the excessive discharge of sewers at this period directly into them without passing over any part of the farm,

97. The crops chiefly grown on sewage farms in India are tobacco, sugarcane, guinea grass, Indian corn (*makai*), and *jowar*, with rotation crops of vegetables, such as cabbage, turnip, carrot and beetroot. For further information on the subject see Appendix B.

98. It is persistently urged by some parties that fluid sewage corrupts the soil over which it is spread and creates a serious nuisance in the neighbourhood of towns, but this objection can only be justifiable in the case of farms on land which is quite unsuitable or insufficient in area to deal with the volumes poured on them from year to year. Under favourable conditions, if a sewage farm produces a nuisance greater than might be reasonably expected from ordinary manured land under cultivation, there is always good reason to suspect gross negligence and mismanagement.

99. **Intermittent irrigation.**—In broad irrigation, the object is to utilize the sewage as far as possible for the benefit of the crops, as also to effect its disposal in a sanitary manner. Land is generally cheap in India and this system of irrigation is well suited for most places in this country Cases may arise, however, in which a sewage farm is desirable where good porous soil is available, but not of sufficient extent to justify a broad irrigation scheme. In such cases it is possible to purify the sewage on the land by suitable treatment, but the expenditure will be relatively greater and the successful raising of crops on the farm will be a doubtful contingency, though still feasible to some extent by proper management. In intermittent filtration the sewage is discharged at intervals in comparatively large volumes over prepared level plots of porous land through which it filters, the purified effluent being carried away to the outfall by a system of agricultural subsoil drains or a natural substratum of gravel. There are two ways of doing this. By one method the flat plots of land are treated like a series of tanks into which the sewage is poured in succession and gradually filters through the porous soil to the drains. Long rests are allowed for the thorough aeration of the land after each submergence, which is further effected, if necessary, by scraping and ploughing. This method combines simple mechanical filtration with bacterial decomposition and is usually effective, but it has the defect that it brings the sewage in contact with the leaves of plants and this is injurious to most crops, so that only special crops can be grown which are not affected by this treatment. The second method overcomes this serious objection and provides copious intermittent irrigation at the same time. It consists in laying out the ground in a series of broad ridges and furrows, the plants being grown on the former and the sewage being run into the latter, *Fig.* 88. A main carrier runs along the upper ends of the

ridges and furrows feedings the latter at suitable intervals. The sewage gradually percolates sideways to the roots of the plants on its way to the subsoil drains. The period of rest between fillings allows of bacterial action on the deposit of sludge in the furrows, if any, and also of aeration of the soil which is further promoted by the subsoil drains if these are properly laid.

Fig 88

As subsoil drainage is seldom or ever necessary in Indian drainage schemes, a detailed description of it is not given in the body of the Manual, but a brief note on the method of laying subsoil drains will be found in Appendix D.

100. **Intermittent sand filtration.**—This method of purification is very similar to that of intermittent irrigation, the only difference being that beds of coarse sand are specially prepared in this case as filters instead of using natural porous soil. The advantage of the system over intermittent irrigation is that it dispenses with the necessity of trying to find suitable land within easy access, as it can be established at any convenient spot, and a less area suffices for a filter of this kind if it is carefully adapted to the local conditions. The same precautions are necessary in the way of ample rest in the intervals between fillings and occasional rakings of the surface to promote aeration and bacterial activity, as the bacterial changes take place in the upper 2 or 3 feet of the filter, it is not necessary to increase the thickness of the sand filter beyond this limit, except over the subsoil drains where a slightly increased thickness is desirable.

101. **Septic tanks.**—The substances present in sewage may be classified as—

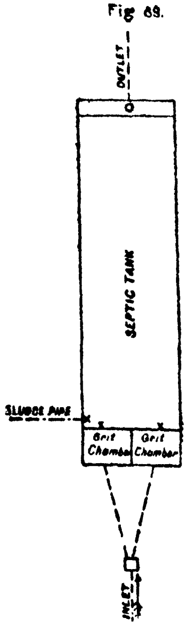
(1) Organic matters in suspension.	(3) Organic matters in solution.
(2) Mineral „ „ „	(4) Mineral „ „

The mineral matters in solution (Chlorides, sulphates, etc.) may be disregarded as they are not of a polluting nature. With the exception of the ammonia salts in solution which are readily converted into nitrites and nitrates by the aerobic nitrifying organisms, the mineral matters are not acted on in any of the stages of purification and they pass through unaltered from the raw sewage to the effluent. The organic matters in solution are dealt with effectively in the filters where they are readily oxidized in the presence of air by aerobic organisms into nitrates. The

heavier matters in suspension, both organic and mineral, are intercepted in sedimentation tanks or grit chambers in the preliminary treatment of the raw sewage. It is the function of the septic tank to dispose of the finer matters in suspension which cannot be dealt with satisfactorily in a filter without clogging the interstitial voids in course of time, and generating foul gases therein by the action of putrefactive organisms. In a septic tank it is believed that anaerobic changes take place in the dark out of contact with the air, and, by liquefaction of the solids, an effluent is produced which can be acted upon and purified by aerobic action in contact beds or filters without clogging them or making them very offensive. Owing to the liquefaction of most of the suspended organic matters, the deposit of large quantities of putrescible organic sludge in the tank is prevented and the chief difficulty of the old systems of purification—the disposal of putrefying sludge—is obviated to a great extent. There is a slight deposit even in septic tanks, but it consists chiefly of mineral matters (sand and road grit) which is non-putrefiable and bears but a small proportion to the suspended organic matters. The mineral deposit accumulates very slowly and septic tanks only require cleaning at very long intervals.

102. A septic tank is generally a long rectangular tank of brickwork or concrete, 6 to 7 feet deep and sunk in the grounds, *Fig.* 89. The floor has a fall of about 1 in 60 from the outlet to the inlet to facilitate the removal of sludge and a grith chamber 4 to 6 feet square to intercept the heavier suspended matter is built at the inlet end. The flow into the tank is continuous and is introduced 2 to 3 feet below the surface not to disturb the bacterial action or the scum which forms at the surface. For the same reason the outlet pipe is also below the surface. The tank is usually made in two or three compartments to allow of one being thrown out of action temporarily for cleaning or repairs, as also to provide for variations in flow and periods of detention at different times of the year. Its size is determined in each case by the climate of the locality. In England such tanks are made large enough to hold a day's supply, but in the hot climate of the plains of India where putrefaction sets in much more rapidly 8 to 12 hours detention will probably be ample in most cases and the tanks need not be so large. The most

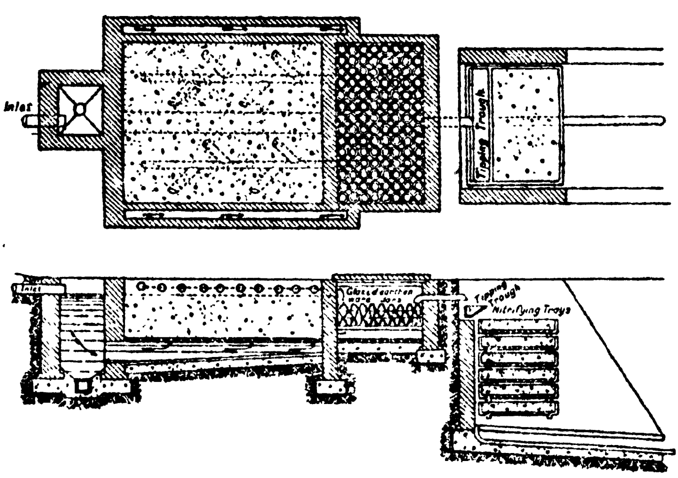
Fig 89.



suitable size for any locality should be decided by an experiment on a small scale in each case. The solids of the sewage seems to undergo a kind of fermentation in the tank with evolution of sulphuretted hydrogen and carbonic acid gases which are strongly malodorous. On the top of the sewage in the tank a scum is formed from an inch to a foot in thickness consisting of the floating matter undergoing decomposition. Owing to this covering of scum, the bacterial changes take place just as well in an open tank as in a covered one. The effluent is putrescible and has to be passed on to land, contact beds, or filters for final purification.

103. **Upward filtration.**—Some time ago it was observed that the slow filtration of sewage through sand in an upward direction was productive of purifying changes in it, if no opportunity was afforded for oxidation in the lower layers. The Scott-Moncrieff system of upward filtration is based on this principle. The treatment of raw sewage according to this system really serves the same purpose as a septic tank in producing the required preliminary anaerobic decomposition in the lower layers in the absence of air ; as the sewage rises upwards some aeration commences in the surface layers favouring the action of aerobic bacteria and the effluent is finally spread by tipping troughs over a series of nitrifying trays containing coke which nitrify the effluent thoroughly by the action of aerobic organisms under conditions most favourable to their growth, *Fig.* 90.* Though this system has

Fig 90.

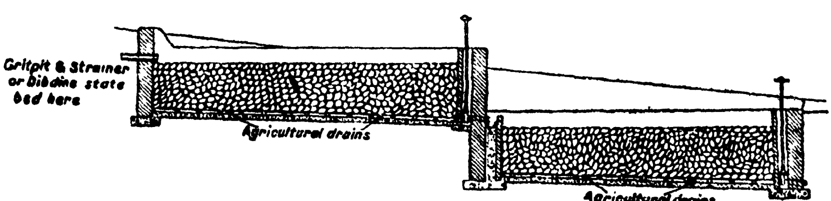


* "Sanitary Engineering" by Vernon Harcourt.

proved satisfactory in several places where it has been tried, it has not been adopted so extensively as the septic tank and filter beds, owing possibly to the greater simplicity of the latter.

104. **Contact beds.**—A contact bed is a watertight tank filled with pieces of stone, burnt clay, clinker, or coke of sizes that would pass through a sieve of 1½ inch mesh and be retained by a ¼ inch mesh. If in impervious soil, it might be simply an excavation in the ground, with or without puddled sides and floor; if on porous soil, it is made of brickwork or concrete.* It is 3 to 4 feet deep. The bed is filled with sewage and allowed to stand full for some time when it is emptied and allowed to rest empty for a certain period, after which it is refilled and the process is repeated. The cycle usually adopted is 1 hour filling, 2 hours full, 1 hour emptying and 4 hours empty, which allows of three operations a day. A full day's rest is given occasionally to each bed in turn. The efficiency of the process is improved by repeating the operation on a second bed of finer material which is known as double contact and occasionally, when a high standard of purification is required a treble contact is resorted to. These contact beds, like all filters, are liable to get clogged by deposit in course of time, but their life is prolonged if some preliminary treatment in septic or sedimentation tanks is adopted for the removal or liquefaction of a large part of the suspended matter before the sewage enters the beds. When the deposit becomes excessive, it is usually removed by flushing the bed with water, or by taking out, washing and replacing the material, a somewhat troublesome and expensive operation. Both filters and contact beds require a fall equal to the depth of the beds if the effluent is drawn off from the floor level, but if this fall is not available it can be reduced materially by connecting the beds

Fig. 91.



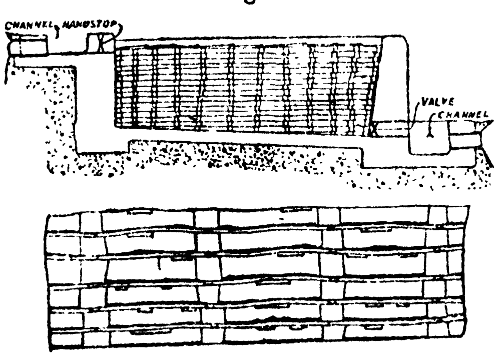
SECTION.

* With reference to this the Royal Commission have remarked as follows:—"In some cases contact beds have been made by simple excavation, but our experience, and the evidence which we have received show that in the majority of cases it is desirable that the beds should be constructed of building materials."

by siphons which fill them automatically in succession. Drawings and a full description of the fittings required for an automatic arrangement of this kind will be found in "Sewerage and Sewage Disposal Apparatus" by Adams—Hydraulics, York, 1904. *Fig.* 91 shows double contact beds arranged in terraces, one below the other, which is the usual method of construction.

105. **Slate beds.**—Septic and sedimentation tanks are always more or less malodorous, and, if placed anywhere near a town or near residential buildings, they are apt to cause a nuisance which is actionable at law. Any form of filtration which would avoid the sludge difficulty and the obnoxious evolution of foul gases from open tanks of putrefying sewage, would therefore appear to be preferable to the tank treatment if the main objection to filters or contact beds that they are apt to clog and putrefy after a time if treated with raw sewage could be removed in some way. Mr. W. J. Dibdin, F.I.C., F.C.S., claims to have met this difficulty by adopting a Multiple Contact system, in which the first contact bed is filled with a series of thin slate shelves instead of coarse ballast; *Fig.* 92 shows the method of placing the slates in position in the beds, the ends being supported on rough slate cubes. The slates are about a quarter of an inch thick, all the vertical distance between them is generally two inches. The dark lines on the surface of the slates show the humus and sewage *débris* formed by the decomposition of the deposit, which layers are said to receive an increment of only one-hundredth of an inch at each filling of the bed with normal sewage. Every fresh deposit is rapidly attacked by living organisms (worms, infusoria, moulds, and bacteria) and reduced in volume to some extent. The slate bed is exactly one-half the size of the second fine contact bed, as the water

Fig. 92.



capacity of the slate bed is double that of the old coarse contact bed. As a substitute for preliminary settling or septic tanks it seems to be satisfactory. Its effluent is less liable to cause nuisance than that of a septic tank and, if properly managed, the sludge washed out of it periodically is practically odourless. This information is taken from notes of a lecture delivered by Mr. Dibdin before the Association of Managers of Sewage Disposal Works at the Royal Sanitary Institute on 8th March, 1911. The system has been adopted with success in several places in England.

106. **Continuous trickling filters.**—The sewage is supplied continuously to these filters in the form of spray instead of being run in intermittently as in contact beds and the ballast is larger than in the beds, its size being from 1 to 3 inches. The tank holding the ballast is not water-tight, but has perforated sides to admit air freely to the body of the filtering material. There is no tank at all sometimes, the material being thrown up in a stack with sloping sides and ends. The depth of the filter is 4 to 6 feet. The object aimed at in these filters is to spread the sewage as uniformly as possible over the whole area in the form of rain or spray and let it trickle down the surfaces of the filtering material slowly without running in a continuous stream. See *Fig.* 93.* The spraying and slow trickling through the open filter secures the thorough aeration of the effluent, and consequently the rate of filtration per cube yard in the case of percolating filters may generally be double that permissible in the case of contact beds. The rate of filtration varies inversely with the strength of sewage, but, for sewage of ordinary strength, it may be taken to be 70 gallons per cubic yard of material. A continuous filter is not well adapted for dealing with raw sewage and preliminary treatment in a septic tank, or screening through a series of strainers, is very necessary. As the working of these filters depends chiefly on the free passage of air through the bed their base should be made as open as possible by the provision of drains or a bottom layer of large pieces of some very hard material.

There are many arrangements for effecting the distribution of sewage over a continuous filter. Some take the form of slotted plates, others of rotating perforated arms and rollers. It is not proposed to deal with these at length in this Manual. They will be found fully described and illustrated in the Catalogues of Makers † of Sewage Disposal Apparatus

* "Sanitary Engineering" by Vernon Harcourt

† Hampbaker & Co., Westminster, London, is one of the leading firms who manufacture appliances of this kind.

and in the numerous text-books on this subject. *Fig.* 93 shows a filter of this description provided with a rotary distributor which revolves automatically and discharges the sewage through a number of holes in the arms, the flow being carefully regulated to pass the liquid at the rate required for thorough purification. All methods of open air distribution are liable to cause nuisance from smell if a strongly smelling liquor has to be dealt with.

Coarse filters of this description do not as a rule give much trouble by clogging, but filters of fine material require careful attention if they have to deal with sewage containing a large proportion of suspended matter or giving rise to fungoid growths. When clogging occurs, the surface material is usually forked and washed with clean water, and the bed is given a rest for ten days or a fortnight.

Fig 93

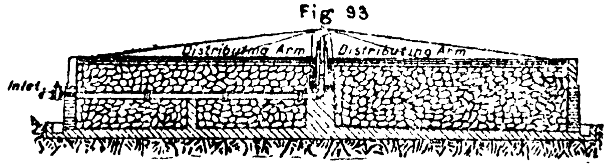
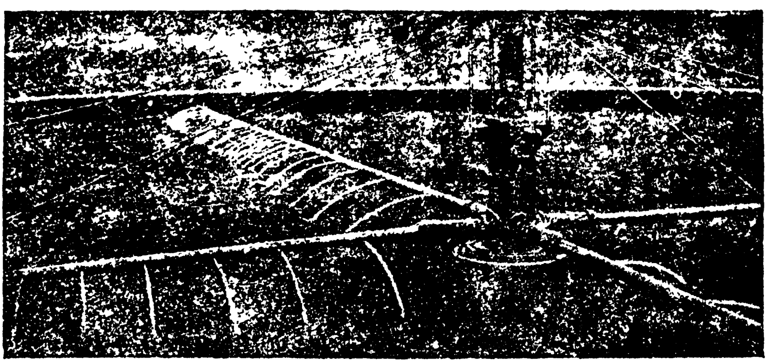


Fig. 94.



107. **Tests of purification** —In the process of purification the organic matters contained in sewage undergo certain changes which are only complete when all the carbon hydrogen and nitrogen it contains are combined with the maximum amount of oxygen they are capable of taking up, or are dissipated in the free state in the form of gas. In the raw state

the substances composed of the above elements are in what is called organic combination. When thorough purification has been effected, all the carbon has become carbonic acid, all the nitrogen, nitric acid, and the hydrogen has formed water ; and these are no longer classed as organic substances but are called inorganic or mineral. To test the degree of purification and enable us to follow the various steps of these changes, samples of the raw sewage and of the effluent are subjected to chemical analysis, details of which will not be given in this Manual as students will learn how this is done in going through their Chemistry course.

108. The analysis of sewage and effluents is, as a rule, carried out by qualified chemists and not by Sanitary Engineers, but the points which a Sanitary Engineer should consider in the analysis statements he usually receives from chemists are the following :—

(1) The solids, suspended and dissolved.

(2) The amount of oxidisable matter as measured by the oxygen absorbed from permanganate of potash under certain conditions.

(3) The nitrous and nitric nitrogen.

The above information is given in Analyst's reports for both the raw sewage and the effluent for comparison.

109. The suspended matter is roughly gauged by a visual examination of the samples in glass cylinders. If it is desired to ascertain the exact amount of both the suspended and dissolved solids, the samples are treated as follows. The total solids are first obtained by evaporating the liquor and weighing the residue. The dissolved solids are next ascertained by evaporating the liquor filtered through paper and weighing the residue of the filtrate. The difference between the two represents the suspended solids. With regard to dissolved solids, their appearance and colour are noted when dried and their behaviour on ignition. The residue of raw sewage is highly coloured and on ignition swells, blackens, and gives off a very offensive odour of burnt urine. A good effluent, similarly treated, leaves a residue that is practically colourless, darkens, but little on ignition and emits no burnt urine odour.

110. The object of the second test is to obtain a measure of the more readily oxidisable matters remaining in the effluent by ascertaining how much oxygen is abstracted in a given time (usually four hours) from permanganate of potash. The absorption of oxygen of raw sewage will be a high figure, as expressed in parts per 100,000, as compared with that of the effluent from a septic tank and the proportion of absorption of a filter

effluent will be much smaller than that of a tank effluent, thus showing that the amount of putrescible nitrogenous organic matter in the final effluent is considerably less and this effluent is, therefore, not liable to further putrefaction to any appreciable extent.

111. The third test furnishes a measure of the purification effected by giving the ratio of oxidised nitrogen (nitric acid or nitrates) to unoxidised nitrogen (nitrous acid or nitrites). The presence of a large proportion of fully oxidised nitrogen in the form of nitric acid is the most reliable test of the quality of a sewage effluent. If nitric acid or nitrates be high and the unoxidised organic matters or ammonia low, the effluent may safely be considered satisfactory.

112. The following table shows how the results of the second and third tests are usually recorded :—

	Parts per 100,000.			
	Ammonia.		Nitric nitrogen.	Oxygen absorbed in 4 hours.
	Free.	Albuminoid		
Crude sewage ..	3·0	0·7	..	10·00
Septic tank effluent ..	3·2	0·34	..	6·45
Filter effluent ..	1·5	0 16	1·72	1·65

In the crude sewage there is a large proportion of ammonia, both free and albuminoid, and a very high proportion of oxygen is absorbed. Owing to the anaerobic changes in the septic tank, the free ammonia in its effluent is slightly increased and the albuminoid ammonia reduced to about half, while the oxygen absorbed is considerably less. In the final filter effluent both forms of ammonia are much less and a considerable quantity of nitric acid has been produced, while the oxygen absorbed has been reduced to about one-fourth only. Where much albuminoid nitrogen exists we have a source of nuisance and, given the requisite conditions, putrefaction will certainly follow. If, on the other hand, we find considerable quantities of nitric acid in a liquid which originally contained much albuminoid nitrogen, we are assured that natural oxidation and decomposition are either complete or will become so without producing any unpleasant or dangerous consequences. The reduction of carbonaceous matters in an effluent can only be deduced from the decrease in the quantity of oxygen absorbed as the oxidised product, carbonic acid, escapes in the form of gas and leaves nothing behind in a form in which it can be estimated.

113. The above results are based on chemical analysis which take time to do and require considerable skill, but there are two rough practical tests of great value which a Works Manager can easily carry out on the works to satisfy himself that he is getting a good effluent. One of these is that the effluent shows no sign of putrefaction on being kept for a number of days (usually seven) in an incubator or enclosed vessel at a uniform temperature of 80° Fahr. A really good filtrate should not develop the slightest offensive smell under such conditions, but in this case it is necessary to see that the effluent is not one which has been produced by sterilization by the addition of lime or otherwise. A temporarily sterilized effluent is always liable to putrefy later, on being diluted to a sufficient extent to prevent the further action of the sterilizing agent. The other practical test is to note the behaviour of an effluent with regard to its absorption of air-derived oxygen dissolved in it. Fish life in water is maintained by this dissolved oxygen and when fish disappear or show signs of distress in water which has become polluted, it is due to the free oxygen in it having been so reduced as to prevent the free action of the respiratory process and not to any direct poison in the water. In water containing much organic matter, the dissolved oxygen is consumed by the micro-organisms in oxidising this matter more quickly than it can be restored by re-absorption from the atmosphere. The capability of the effluent to support fish life is therefore a very valuable practical test of the quantity of dissolved oxygen and putrefying matter in it.

114. The putrefaction test is readily made by filling a bottle with a sample each day for seven days. The first bottle is examined on the eighth day and it is then emptied and refilled with a fresh sample. All the bottles are thus examined in rotation at a fixed hour each day after a period of seven days and refilled. The temperature of the closed vessel in which the bottles are kept should, as far as possible, be maintained at 80° Fahr. The examination should be made *regularly*, every day, of each of the seven bottles or its value will be greatly diminished.

115. To make the fish test, a globe or aquarium with a few gold fish should be kept on the works and filled each day by the effluent to be tested. The greater part of the water in the globe should be drawn off each morning by means of a syphon and be replaced by an equal quantity of the day's sample after it has been well shaken. If the fish live and do not show any signs of distress, it may safely be assumed that the effluent is sufficiently aerated. The fish will require feeding occasionally.

116. An important point to be looked to in having effluents tested is the time that elapses between collection and analysis. All the samples

should be delivered to the analyst as quickly as possible and the date and time of collection should be noted on the vessels in which they are sent. It should be remembered that microbes are active in bringing about putrefactive changes even after an effluent has been put in a bottle, and even crude sewage may appear on analysis to be good if it is kept in the laboratory for a month or two.

117. **General conclusions.**—In concluding this chapter, the Author thinks it would be useful to give a summary of the conclusions and recommendations of the Royal Commission which has recently investigated the subject of sewage disposal. The following is an extract from their Fifth Report, dated 1908 :--

It is practicable to purify the sewage of towns to any degree required, either by land treatment or by artificial filters, and there is no essential difference between the two processes.

The main questions, therefore, to be considered in the case of a town proposing to adopt a system of sewage purification are, first, what degree of purification is required in the circumstances of that town, and of the river or stream into which its liquid refuse is to be discharged; and secondly, how the degree of purification required can, in the particular case, be most economically obtained.

Removal of Suspended Matters.

We find that it is generally desirable to remove from the sewage, by a preliminary process, a considerable proportion of the grit and suspended matters, before attempting to purify the sewage on land or filters.

Sedimentation Tanks.

Quiescent Sedimentation.—Two or three hours' quiescence is usually sufficient to produce a tank liquor fairly free from suspended solids, but owing to the fact that some sewages contain a larger proportion than others of solids that settle very slowly, no general rule can be laid down as to the necessary period of quiescence. With this form of treatment the deposit in the tanks should be frequently removed.

Continuous Flow Sedimentation.—The amount of settlement effected does not depend alone upon the period of flow, but upon a number of other factors. If the tank liquor is to be treated upon filters of fine material, the period of flow should generally be from 10 to 15 hours. The tanks should be cleaned out at least once a week.

Septic Tanks.

All the organic solids present in sewage are not digested by septic tanks, the actual amount of digestion varying with the character of the sewage, the size of the tanks relative to the volume treated, and the frequency of cleaning. With a domestic sewage, and the tanks worked at a 24 hours' rate, the digestion is about 25 per cent.

The liquor issuing from septic tanks is bacteriologically almost as impure as the sewage entering the tanks.

Domestic sewage which has been passed through a septic tank is more easily oxidised in its passage through filters than domestic sewage which has been subject to chemical precipitation or simple sedimentation.

No definite rules can be laid down as to how long a septic tank should be run without cleaning. In the case of small sewage works (serving populations of say 100 to 10,000 persons) the tanks should generally be allowed to run, without cleaning, so long as the suspended matter in the tank liquor shows no signs of affecting the filters injuriously.

For larger works it would generally be advisable to run off small quantities of sludge at short intervals of time.

The rate of flow through a septic tank is a matter in which the needs of each place require special consideration, but at few places should the sewage be allowed to take longer than 24 or less than 12 hours to flow through the tank. In no case should less than two tanks be provided, and they should be so arranged that, if necessary, one tank can be used alone.

As regards digestion of sludge and quality of tank liquor, a closed tank possesses no advantages over an open tank. There is less risk of nuisance if the tank and the feed channels to the filters are covered in.

By passing septic tank liquor through tanks of a size sufficient to hold about one quarter of the day's flow, with the addition of from 2 to 3 grains of lime per gallon to the liquor, the suspended solids in the liquor are materially reduced, a considerably larger quantity of the liquor can be treated per cube yard of filter, and the offensive character of the liquor is largely destroyed.

Chemical Precipitation.

In the case of sewages which contain certain trade waste, and strong sewages from water closet towns, it is generally desirable to subject the sewage to some form of chemical treatment before attempting to oxidise the organic matter contained in it. In most cases careful chemical precipitation materially aids the deposition of the suspended solids, and facilitates subsqueut filtration.

No general rule can be stated with regard to capacity of precipitation tanks. With continous flow an eight hour rate is usually sufficient to produce fairly good tank liquor from a domestic sewage of average strength.

If sewage is allowed to remain quiescent in the tank, two hours' settlement would usually suffice.

Relative Cost of Different Tank Treatments.

In the absence of special circumstances favouring a particular plan, it would appear that there is very little difference in annual cost between the various methods of tank treatment when taken in conjunction with the cost of subsquent filtration through percolating filters, assuming that the kind of filter adopted in each case is that which is best adapted to the particular tank treatment provided.

Filters.

Within ordinary limits, the depth of a contact bed makes, practically, no difference to its efficiency per cube yard.

We think that it would be generally inadvisable to construct contact beds of a greater depth than 6 feet or of a less depth than 2 feet 6 inches.

For practical purposes, and assuming good distribution, the same purification will be obtained from a given quantity of coarse material, whether it is arranged in the form of a deep or of a shallow percolating filter, if the volume of sewage liquor treated per cube yard be the same in each case.

With regard to percolating filters of fine material, if the liquid to be purified were absolutely free from suspended and colloidal solids, and if thorough aeration could be maintained, the statement just made for filters of coarse material might possibly hold good for filters of fine material also. In practice, however, these conditions can scarcely be maintained with larger rates of flow, and we think that the greatest efficiency can be got out of a given quantity of fine material by arranging it in the form of a shallow filter rather than of a deep filter. But we are not in a position to make an exact quantitative statement as to the difference in efficiency of the two forms.

The amount of sewage which can be purified per cube yard of contact bed or of percolating filter varies—within practical limits nearly as inversely as the strength of the liquor treated. This statement is based on the assumption that the size of the material of which the filter is composed is, in each case, suitable to the character of the liquor treated and that the material is arranged at the proper depth to secure maximum efficiency.

Detailed particulars as to the amounts which can be treated per cube yard of filter are given on page 117 of the report.

Taking into account the gradual loss of capacity of contact beds, a cube yard of material arranged in the form of a percolating filter will generally treat about twice as much tank liquor as a cube yard of material in a contact bed.

In the case of sewage containing substances which have an inhabitory effect upon the activity of micro-organisms, the working power per cube yard of filter of either type may be more nearly equal. This point, however, is not clearly established.

Percolating filters are better adapted to variations of flow than contact beds.

Effluents from percolating filters are usually much better aerated than effluents from contact beds, and, apart from suspended solids, are of a more uniform character. On emptying a contact bed, the first rush is usually much more impure than the average effluent from the bed.

The risk of nuisance from smell is greater with percolating filters than with contact beds.

With percolating filters there is apt to be nuisance from flies, especially with filters constructed of coarse filtering material. In the warmer months of the year such filters swarm with members Psychodidae, which, though appearing to breed and develop in the filters, may usually be seen in large numbers on the walls of houses or buildings close to or on the works.

Treatment of Sewage on Land.

There is no essential distinction between effluents from land and effluents from artificially constructed filters.

Effluents from those soils which are particularly well adapted for the purification of sewage contain only a very small quantity of unoxidised organic matter, and are usually of a higher class than effluents from artificial filters as at present constructed and used.

Effluents from soils which are not well adapted for purification of sewage may often be very impure.

Effect of Trade Effluents on Sewage Purification.

All the trade effluents of which we have had experience interfere with or retard processes of purification to some extent, but we are not aware of any case where the admixture of trade refuse makes it impracticable to purify the sewage upon land or by means of artificial processes, although in certain extreme cases special processes of preliminary treatment may be necessary.

Nuisance from Smell.

All sewage works are liable, at times, to give off unpleasant smells; they should, therefore, be situated away from dwelling houses, wherever this is practicable.

The nuisance is apt to be considerably greater where the sewage contains brewery refuse in any quantity; but, on the other hand, the presence of some trade effluents, such, e.g., as iron salts or tarry matters, tends to rendar the process of purification less offensive.

The extent of the risk of nuisance depends, however, not only on the character of the sewage, but also on the method of treatment adopted.

General Observations bearing on Choice of a Method of Sewage Treatment.

The selection of a method of sewage disposal should depend primarily on local conditions.

If a sufficient quantity of good land, to which the sewage can gravitate, can be purchased for about £ 100 an acre, land treatment would usually be the cheapest method to adopt.

In cases where only clay is available, it would generally be cheaper and more satisfactory to provide artificial filters.

Given conditions favourable to each process, there is little difference as regards cost between any of the different forms of tank treatment when these are considered along with the cost of subsequent filtration.

Single contact will, generally, only yield a good effluent where the sewage to be treated is weak, and then only after good preliminary treatment. For purification of partially settled weak sewage, and for well, as also for partially settled sewage of average strength, if the case is one in which a good effluent is required, double contact is necessary, unless the preliminary treatment is exceptionally good.

In nearly every case a greater rate of filtration per cube yard can be adopted if the material is arranged in the form of a percolating filter, than if it is used in contact beds. In many cases the rate of filtration through percolating filters may be double or nearly double what it could be with contact beds.

Where the liquor to be treated contains much suspended matter, it is usually advisable to construct filters, whether contact or percolating, with coarse filtering material. Where the preliminary treatment has effectively removed the greater part of the suspended matter, it is best to use fine material in the filters.

Test for Sewage Effluents in Relation to Standards.

According to our present knowledge, an effluent can best be judged by ascertaining first effluent, the amount of suspended solids which it contains, and second, the rate at which after the removal of suspended solids, takes up oxygen from water.

In applying this test it is important that the suspended solids should be removed, and estimated separately

For the guidance of local authorities we may provisionally state that an effluent would generally be satisfactory if it complied with the following conditions :—

(1) that it should not contain more than 3 parts per 100,000 of suspended matter ; and

(2) that, after being filtered through filter paper, it should not absorb more than—

(a) 0·5 part by weight per 100,000 of dissolved or atmospheric oxygen in 24 hours,

(b) 1·0 part by weight per 100,000 of dissolved or atmospheric oxygen in 48 hours, or

(c) 1·5 parts by weight per 100,000 of dissolved or atmospheric oxygen in 5 days.

118. In fixing standards of purification of effluents, the Royal Commission have decided to adopt the test of dissolved oxygen absorbed in 5 days in preference to the ordinary test of oxygen absorbed from permanganate

in 4 hours. The latter is a chemical test which destroys all bacteria and is only a rough measure of the carbonaceous strength of the sample examined, apart from cellulose and fat on which it has little or no action. They consider this test a good rough guide for arriving at the *relative* degree of oxidisability of different samples, but, though it requires a much longer time to carry out, they prefer the other test as being more reliable for comparison with standards as it is a biological process which is more definite and complete in its action.

The amount of oxygen a sample requires for oxidation is determined by the dissolved oxygen test by keeping a definite quantity of the sample in contact, in a closed bottle, with a known excess of oxygen in well aerated tap water or atmospheric air until it is completely oxidised and measuring the oxygen left in the water or air after the period of test.

119. Students requiring further information on this or any other point connected with sewage disposal will find full details and the latest opinion of experts in the report of the Royal Commission on Sewage Disposal, 1902-1912.

APPENDIX A.

Extract from "Directions for the preparation of a drainage project" issued by the office of the Sanitary Engineer to Government, United Provinces of Agra and Oudh.

II.—A drainage project will consist of :— **The project.**

(1) One index sheet.

(2) The report

(3) The general specification.

(4) The detailed specification

(5) The street drain statements.

(6) The main drain statements.

(7) The detailed analysis of rates for :—

(a) Each type of street drain.

(b) „ sewer or main drain.

(c) „ gully pit.

(d) „ detritus pit.

(e) „ manhole.

(f) „ street drain crossing.

(g) Flushing tanks

(8) The detailed estimate of each culvert, storm overflow or other special building works necessary as far as possible to foresee.

(9) The detailed estimate of any pumping plant engines, houses, quarters, etc., necessary.

(10) The abstracted estimate for each drainage block to be attached to the street drain statement for each block.

(11) A final abstract showing the quantities and the cost of each block, and the quantities and cost of the main drains under the different sub-heads of work.

(12) The final abstract of the estimate showing :—

Total cost of work.

Percentage for establishment.

„ contingencies.

Sanitary Engineer's fees, 3 per cent. on the first Rs. 50,000 and 2 per cent. on remainder.

Acquisition of land.

(13) Any special calculations that the exigencies of the scheme may render necessary

III.—The first requirement for a drainage project is a map of the municipality showing all the streets, houses, kachcha and pakka wells, existing drains, natural or artificial, municipal boundary and prominent features, cultivated area, etc. When this is obtainable (it may have to be made or it may be existing), it must be covered with the following information :— **Survey and preliminary work.**

(1) Levels of the surface of each street, and of the ground at every 100′ or wherever a level is necessary as at the junction of side streets, and in the case of relatively low-lying ground the plinth or floor level of the houses, in black ink.

(2) Levels of the bottoms of existing drains in blue ink.

(3) Position and diameter of all pakka wells, the level of water surface and level of bottom of well.

(4) If there is a river, its ordinary and high flood level.

(5) Position, number and reduced level of all bench marks. (This information is very important, and the bench marks should invariably be taken on some spot easily found and not likely to be disturbed, such as the plinth of a building, the parapet of a culvert, a stone threshold. A list of bench marks giving number, reduced level and description of where it is to be found should be made out and attached to the project. It is convenient if pasted on the inside cover of the map casing—.)

(6) The field-book should contain ample notes showing what streets are metalled, what paved, and what kachcha with their widths, etc.

Preparation of the detailed project.

IV.—When the map is ready, the real work of the scheme commences

(a) It will generally be found that there is a watershed running through the town. This should be clearly marked. The main drains will then be lined out after a personal inspection of the whole locality. When the alignment of the main drains has been finally settled, the map can then be divided off into areas called blocks, each area being drained by its own sub-main drain which eventually drains into the main drain. The levels of the main drain are to a certain extent determined by the levels of the sub-main drains falling into it.

(b) Each block is traced separately from the main map, under it are plotted the longitudinal sections of its more important drains.

(c) At the same time the statements are prepared. These statements contain all the information required for *every single street and drain* in the municipality.

(d) The type of drain to be used is determined by the area and population served and the gradient obtainable. The population determines the amount of sullage taken at 2 gallons per head per hour. The area determines the quantity of storm water the drain has to carry, allowing one-tenth of an inch per acre. In the main drains ¼ inch per acre will be allowed, and when the rainfall is heavy, ¼ inch may be allowed for the side drains aslo.

To simplify these laborious calculations a statement of velocities and discharges has been drawn up for all the standard types of street drain section for all ordinary gradients, and the types of the drain to be used in each case will be selected from this statement.

(e) These calculations will all be shown on the statement and the population and area of each block marked on its plan. It is not possible to show the population and area served by each drain, however, and these will be calculated separately. When the records give muhalla populations, these will be taken as far as possible. If not, a density average will be struck, and the population calculated from the area.

(f) The statements will also give full information showing what is to be done to the road itself apart from the drain. These details will be discussed with the Municipal Chairman and Secretary, so that no streets or lanes are taken up which are not to be brought into the scheme. This part of the statement takes a long time, and necessitates going over all the city with the map

(g) In order to be able to distinguish each drain the following nomenclature will be used:—

Taking one block L. See specimen* sheet. Its main drain will be called L, and, commencing on the right hand side of the drain nearest its junction with the main, all the drains will be numbered in rotation $\frac{L}{1}$, $\frac{L}{2}$, $\frac{L}{3}$, etc, proceeding from outfall to summit on the right hand side of the sub-main, and from summit to outfall on the left hand side. Drains running into $\frac{L}{1}$ are numbered $\frac{L}{1}a$, $\frac{L}{1}b$, $\frac{L}{1}c$. Drains running into $\frac{L}{2}$ are numbered $\frac{L}{2}a$, $\frac{L}{2}b$, $\frac{L}{2}c$, and so on.

(h) The longitudinal sections of the drains will show where and to what level the drains fall in. The sections will also give—

Gradients.

Distances.

Catchment area.

Population.

Sullage { Discharge. Velocity.

Storm water and sullage { Discharge. Velocity.

Type no.

Reduced level of proposed drain.

" " ground.

Depth above or below centre of road.

Filling or cutting for road dressing.

V.—The final disposal of the sullage will be settled in consultation with the Chairman. If disposed of on a sullage farm, a map of the proposed sullage farm contoured with levels all over it will be attached to the project. **Sullage disposal.**

VI.—The maps, plans and drawings required will be— **Drawings required.**

(a) An index map showing the alignments of the main drains, position of sullage farm and the more prominent features of the town, scale 16 inches to the mile, or any tracing from an existing map of convenient scale.

(b) A map of the municipality showing all the streets, lanes, houses (pakka and kachcha), cultivated areas, the alignment of the main and street drains and their outfall or outfalls, and the sullage farm area with levels all over it, if there is a sullage farm, or the river if the sullage is discharged into a river. Scale 100′=″1.

(c) A similar map, traced from (b) but simply showing all the drains and the drainage blocks, the area and population of each block and the levels to which the drains have to be put in, position of wells and flushing tank bench marks, etc. Scale 100′=1″.

(d) The plan and longitudinal section of each main drain. These sections will contain the information noted in paragraph IV (h) above. Scale 200′=1″ horizontal, 10′=1″ vertical.

(e) Plans of each of the blocks showing the drains in that block, and under these plans will be plotted the sections of the principal street drains in the block. These sections will also give all the information noted in paragraph IV (h) above. Scale for plan same as (b); scale for section same as (d).

*Not printed.

(*f*) Type plans of all the street drain sections to be used. There are printed copies of these.

(*g*) Drawings of all sewers.

(*h*) Drawings of manholes, detritus pits, gully pits, drain crossings, flushing tanks. Most of these are standardized, scales 2′, 4′ and 8′=1″.

(*i*) Drawings of all road culverts. Scale 2′ and 4′=1″.

(*j*) " " special arrangements such as storm overflows, new roads, etc. Scale 2′ or 4′=1″.

(*k*) If there is a pumping plant, the special drawings required for the housing of engine and pumps and engine staff. Scale 4′=1″.

The report.

VII.—The report should contain a clear and concise account of the whole scheme arranged more or less under the following heads :—

Preliminary history.

(*a*) A brief account giving the steps which have led up to the inception of the project.

Area and population.

(*b*) The area and population within municipal area, the area of inhabited portion and the area of uninhabited portion, the density of population per acre or, if obtainable, the actual population of each muhalla, whether the population has increased since the last census and the reasons for such increase and the figures it is proposed to take as the basis of calculation.

General description.

(*c*) A general description of the scheme, giving as shortly and concisely as possible the alignments of the principal drains and sewers, and stating what existing drains and other work will be worked into the scheme without alteration and what work will require alteration or reconstruction, what areas, if any are not included, and whether they can be eventually included at a future date

Sullage disposal

(*d*) A description of how it is intended to dispose of the sullage, and, if put on to a sullage farm, the area of land it is proposed to acquire.

Details

(*e*) The detail of the work to be done in every street in each block will be found in the statement sheet for each block.

Rates.

(*f*) The detail of rates will be found worked out for the different types of drains and sewers and for the manholes, gully pits, crossings, etc., from page——to page——of the estimate.

Agency for carrying out the work.

(*g*) The agency by which the Board is recommended to carry out the work, and the supervision necessary.

Financial aspect and amount of work the Board can finance.

(*h*) A short note of the financial capabilities of the Board (to be obtained from the Chairman), the amount the Board can finance and what work it is recommended should be carried out, working up as nearly as possible to this amount.

(*i*) Generally the report should endeavour to put before the Board exactly what they are going to get in as plain language as possible.

APPENDIX B.

Extract from the report on the treatment of sullage in the United Provinces of Agra and Oudh, by Gilbert J. Fowler, D. Sc., F.I.C., F.R. San. Inst., etc., Lecturer in Bacteriological Chemistry, Public Health Department, University of Manchester, Consulting Chemist to the Rivers Committee of the Corporation of Manchester (1909).

Quantities of sullage treated per acre.—It would be of interest to carry these comparative observations further in order to obtain a set of standards for soils in different parts of the province suitable for receiving sullage.

If, at the same time, careful observations were made extending over a considerable period of time as to the volume of sullage which could safely be treated on soils of known character, data would be obtained which would afford a fairly accurate estimate of the quantity of land which should be taken up in any given case.

Thus, for example, the quantity of sullage capable of being dealt with efficiently and without danger of nuisance by the Agra sullage farm is given as 15,000 gallons per acre. Taking everything into consideration, the porosity of the soil, the amount of sewage dealt with on less porous soil in Europe, and the character of the liquid to be treated, I consider this is a safe quantity. That being so, I should expect from the soil examination that rather less should be dealt with by the Wingfield Park* land and less still at Gullala-har. What the exact quantity should be in these latter cases cannot, of course, be determined, otherwise than approximately, till more data are available.

Provisionally one might suggest 12,000 gallons per acre for Wingfield Park and 8,000 for Gullala-har, the soil at the latter spot being obviously much finer than either at Agra or at Wingfield Park and also containing more organic matter as shown by the loss on ignition.

No doubt it would be possible by careful management to deal with larger quantities than these in all the three cases considered, but a large margin must always be left for inattention in this respect as any failure would rapidly lead to ponding and consequent nuisance, either from smell or from mosquitoes, the larvae of "culex," at any rate thriving, to my personal knowledge, in small pools of polluted water.

On the other hand, greater latitude could be allowed where the character of the farm area approximated to anything like Chambal sand as used at the Agra water-works. Similar sands are found in large quantities in Madras and it is easy to see from the figures of the mechanical analysis that much greater quantities of water can be filtered through this sand than through the sand obtained from the adjoining bed of the Jumna.

The sands of the Agra and Lucknow farms are probably, however, more typical of those likely to be met with in the United Provinces.

Solid matters in sullage applied to land.—A question of importance in connection with the treatment of sullage upon land is the provision or otherwise of preliminary settling tanks. This point was especially considered and the samples of suspended matter from Lucknow and Agra sullage were carefully examined. Moreover, the samples of soil from Agra farm were especially chosen, as can be seen from the table, with reference to this point. It is evident from the results that the greater part of these suspended solids consists of mineral matter not greatly differing in composition from the actual soil of the farm. At most (e.g., in the sample of wet sullage from Lucknow) the loss on ignition of the finest material is less than 14 per cent. and there is very

*At Lucknow.

little greasy matter as determined by the other extract. Microscopical examination also does not reveal such quantities of cellulose fibre as would be likely to form any felting of the surface.

Under the circumstances and having regard to the rapidity of evaporation during the hot weather, I do not consider it necessary to provide tank treatment before passing sullage on to the farm. Such tankage is not unlikely to cause a nuisance from the products of irregular anaerobic fermentation. Experiments by the writer have shown that latrine sewage, while capable of being treated anaerobically without nuisance if the operation is carefully conducted, may give rise to very offensive odours if the fermentation is not systematically developed, especially in the early stages. The constant irregularities which would be occasioned by the rapid accumulation and withdrawal of solid matter in the case of sullage would increase the liability to nuisance at tropical temperatures. Indeed, the chief cause of possible nuisance in the farm at the time of my visit was the main inlet channel, where considerable deposit, followed by fermentation, was taking place. I agree with the suggestion of the Sullage Farm Committee that this channel should be narrowed and constructed in stoneware or concrete in such a way as to reduce the formation of deposit to a minimum.

In this connection a further sample No. 10 of dry sludge from Lucknow biological installation is of interest as showing, on the other hand, how rapidly nitrification is set up when free access of air is allowed.

Under these circumstances, therefore, it would appear likely that the direct treatment on land of sullage containing all its suspended solids is advantageous as being less likely to create nuisance than when tanks are provided and as rendering the soil more suited for agricultural purposes both by the development of nitrates and also probably the simultaneous formation of humus.

At the same time it must not be forgotten that in course of time such suspended solids will tend to reduce the porosity of the soil, and consequently afford a further reason for liberal provision of land in the first instance.

The growth of crops.—In considering the question of what crops are most suitable for growing on sullage or sewage farms, four main conditions have to be borne in mind :—

(1) The crop should be capable of absorbing large quantities of water at all stages of growth.

(2) The crops when grown should be of the highest commercial value.

(3) The crop should not be liable to produce nuisance from the possible rotting of residual leaves and roots.

(4) No part of the plant intended for human consumption in the raw state should come in contact with the liquid.

The first consideration would eliminate cereals as they must be left unirrigated at certain periods of their growth and at no time are capable of absorbing very large quantities of water.

Rye-grass fulfils condition No. 1 and several crops can often be raised in one year. This is done, e.g., in Madras, with profitable results, but I understand that the demand for grass in the United Provinces is satisfied from sources other than sullage farms.

Cabbages and turnips are unsuitable under condition 3 as they are very likely to create a nuisance, unless all leaves and roots are very carefully cleared away after cutting.

Where the ridge-and-furrow system of irrigation is carefully carried out, certain salad plants, e.g., lettuce, can be cultivated without serious risk. As the native in India, however, appears to be wedded to surface irrigation as already described, it will be wisest

to prohibit altogether the growing on sullage farms of vegetables intended for human consumption in the raw state. In France such plants are forbidden to be treated with sewage from the time they appear above the surface.

All the four conditions mentioned are satisfied by such crops as tobacco and sugarcane which grow luxuriantly on sullage farms and from which excellent economic returns are obtained.

In view of the extreme porosity of the soil and the character of the liquid to be dealt with a few general observations suggest themselves.

In the first place, I do not advise the general provision of underdrains. The water gets away sufficiently rapidly without them and consequently the expense of laying drains is not necessitated by any danger of the land becoming water-logged. At most, it should generally suffice if one or two main drains are laid in order to depress the level of the sub-soil water. There are, as a matter of fact, certain possible dangers in the systematic provision of underdrains. The unpurified sullage is apt to find its way to them by natural "short-cuts" even if, as sometimes unfortunately happens in England, such short-cuts are no tpurposely made in order to dispose of inconvenient quantities of liquid.

On the other hand, careful observations should be made of the direction of flow of the sub-soil water under various conditions of water level in the stream into which the effluent will ultimately pass, so as to avoid any possibility of pollution of drinking water wells which may be in the neighbourhood.

It need scarcely be said that the site of a sullage farm should be chosen as far as possible from the locality of any such wells.

At the same time there are decided advantages in the provision of wells for irrigation purposes only. There will probably be an appreciable difference in the amount of water absorbed by the land in the hot and cold weather respectively, and at the beginning and end of the rains. For these and other reasons previously mentioned the area under irrigation should be such as to be readily capable of taking the sullage under the worst conditions. It may therefore sometimes happen that in the dry periods the sullage may need to be supplemented by well water. Further, there may be occasions when a certain amount of dilution is beneficial. I noticed one or two plots which had evidently from the state of the crop been "over-sullaged" and I understood that this arose more from the strength of a particular dose of sullage than from its quantity. A supply of water at hand for occasional dilution, as experience showed it to be necessary, would be advantageous under such circumstances.

In the case of *sewage*, as distinct from *sullage*, preliminary tank treatment is desirable for reasons which have been already explained. The general principles which govern the treatment of the effluent from such tanks are the same as for sullage. It will probably be of a more uniform character and therefore require rather less careful judgement in its application to crops than in the case of sullage, for which as already explained tank treatment is, on the whole, better dispensed with.

APPENDIX C.

Extract from a selected paper in volume CXXXV of the Proceedings, Inst. of C. E, by Strachan, on the Karachi Sewage works.

Population of city, 30,000 ; *area of city dealt with,* 175 *acres.*

The sewage is discharged at the farm, at a level of 59·70 feet above level of the discharge pipe of the lowest ejectors, into a tank of 15,000 gallons capacity, provided with an automatic syphon, so that its contents could be discharged on the farm in a few minutes. It was found, however, that the discharge from the full tank was greater than the men in charge of its distribution could conveniently cope with, and, accordingly, arrangements have been made whereby the sewage is discharged on the farm at the same velocity as it flows from the main.

The land reserved for the sewage farm measures about 800 acres, but the area at present laid out is 60 acres. The farm is intersected by masonry channels or carriers for a certain portion of its area, and for the rest the carriers are of earth. The site of the farm slopes from the foot of the Mangah Pir hills to the Lyari river, and is fully exposed to the strong breezes which blow from the sea from April to October. These breezes have a most damaging effect on all plant life ; efforts have therefore been made to afford to the crops as much shelter as possible by dividing the farm into 4 acre blocks running round each block cart roads, along the sides of which trees have been thickly planted. The soil of the farm varies between light sandy loam and hard black caking earth several feet thick ; the subsoil is all gravel. Water is not to be found nearer the surface than 18 feet. Various plans for irrigating the fields were tried and were abandoned as unsuitable. That now followed gives satisfaction from a sanitary point of view, inasmuch as the sewage is not only quickly disposed of but the land is irrigated without any offensive smell. Each field measures one acre, and, for irrigation, it is divided into beds 20 feet wide and the full length of the field (198 feet).

The sewage, which is brought to the upper end of the ground in earthen channels, is run on to a bed till it has reached about three-quarters of its length, it is then turned on to another bed, and the same process is repeated until the whole field has been irrigated. The fields have a fall of 44 inches per 100 feet and the sewage, which is cut off when it has reached three-quarters of the length of the field, is sufficient to irrigate the whole bed before it ceases flowing. There is no effluent from any field. The whole of the liquid part of the sewage is either evaporated by the sun or is absorbed by the soil within a few hours after it is run on to the field. A watering once in 8 or 9 days is sufficient for all the crops yet tried on the farm.

The following are the crops already tried :—

Guinea-grass	Panicum Jumentorum.
Lucerne	Medicago Sativa.
Chubber	Cynodon Dactylon.
Italian rye-grass	Lolum Italicum.
Sugarcane	Saccharum Officinarum.

These crops may be called perennials, as, with the exception of sugarcane, they will, under favourable circumstances, continue growing for several years without being re-sown. All have grown well and have given heavy yields.

Juar	Sorghum Vulgare.
Bajri	Panicum Spicatum.
Makai, or Indian corn	Zea Mays.
Wheat spelt	Triticum Speltix.
Common barley	Hordeum Vulgare.
Millet	Panicum Miliaceum.

With the exception of barley, which tillered too much and the stalks of which were too weak to support their own weight, all the above crops did well. Indian and European vegetables also proved successful. Guinea-grass forms a good crop for a sewage farm; 2 acres were planted during April, 1895, and the yield to the end of March, 1896 was 196,507 lbs. of green fodder. In the climate of Karachi lucerne yields all the year round, but its period of most luxuriant growth is the cold season, from the beginning of November to the end of March. A plot measuring one acre gave four cuttings between those dates, the combined weight being 30,385 lbs. The quantity of seed used was 30 lbs. to the acre. Chubber, unlike lucerne, is of slow growth during the cold season; 2 acres under this crop yielded in all 33,189 lbs. between the dates mentioned. Italian rye-grass sown in the cold season yielded in the first cutting 13,475 lbs. from 2 acres. Of sugarcane the yield was 4,383 canes from ½ acre, from the beginning of November to the end of March. This was not considered a satisfactory crop. Juar grew well till it was attacked by caterpillars, from the effects of which it suffered greatly. Bajri is not a favourite fodder, yet cattle seem to thrive very well on it; it is not subject to the attacks of moth larvae. A crop occupied the ground 51 days and yielded 27,450 lbs. from 1 acre. Of green fodder, makai or Indian corn has a ready market in Karachi. It is a very suitable sewage farm crop, occupying the ground for only 2½ months. It yields between 16,000 lbs. and 24,000 lbs. per acre of green fodder. Unfortunately it is very subject to the attacks of moth caterpillars. Wheat spelt or wheat barley proved more satisfactory than ordinary barley. An acre sown on the 15th December, 1895, was ready for cutting as green fodder on the 15th February, 1896. The harvest continued until the 1st March, 1896, and the quantity realized was 25,240 lb. Common barley is not considered a suitable crop for a sewage farm. Common millet was little known in the neighbourhood until it was tried on the sewage farm in Karachi. An acre sown on the 7th December, 1895 was fit for cutting on the 11th February, 1896, or a little over two months from the date of sowing. The harvesting continued as the grass was required up to the 3rd March, and the total quantity harvested was 25,887 lbs. to the acre. This crop can be grown in Karachi all the year round, but it is best suited for the cold season.

The following is a statement of the number of gallons of sewage delivered on the farm by the ejectors during 12 months ending June, 1896, and for the six months ending the 31st December, 1896:—

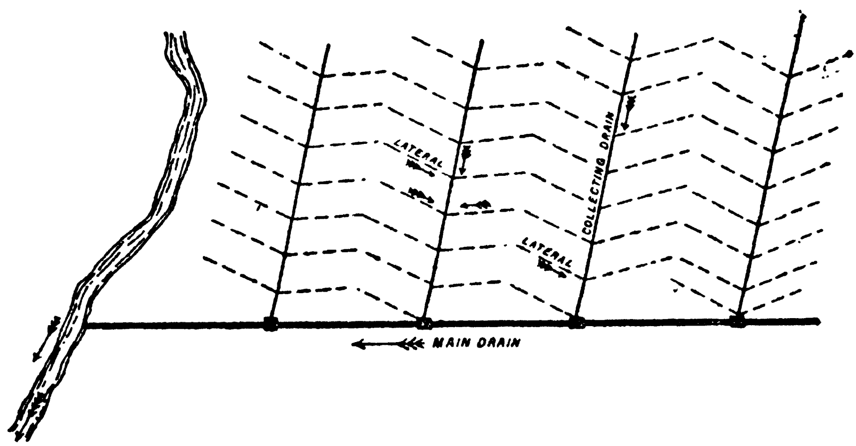
	Gallons delivered	Cost.	Cost per 1,000 gallons.	
		Rs.	Annas	Pies.
From 1st July, 1895 to 30th June, 1896.	60,360,000	10,308	2	8·75
From 30th June to 31st December, 1896.	42,518,257	7,543	2	10·0

APPENDIX D.

Note on subsoil drainage.

Surveys.—The first step towards carrying out subsoil drainage is to make a contoured plan of the surface and to get as much information as possible regarding the character and surface of the dense subsoil below and the level of the ground water, if these are anywhere near the surface by making numerous trial holes especially on the valley lines and watersheds. The collecting subsoil drains should follow the water-courses of the surface of the impervious subsoil rather than the configuration of the top surface.

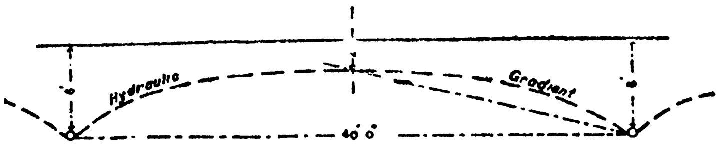
Drainage plan.—For intermittent filtration, the subsoil drainage scheme will have to be arranged in a number of small blocks corresponding with the filtration beds, each delivering, through open jointed laterals and collecting drains, into a main water-tight drain so that each plot or small group of plots may be separately drained. The following diagram shows the usual arrangement of main, collecting and lateral drains :—



Size and gradient.—The lateral drains should be agricultural earthenware pipes without collars not less than 2½ inches in diameter, laid at uniform gradients of not less than $\frac{1}{200}$ at a minimum depth of 4′ 6″ below what, is to be the finished surface of the ground. The collecting drains should be similar pipes 3″ to 4″ diameter. The mains should be glazed socket pipes 4″ to 6″ diameter with cement joints, the size, depth and inclination being so arranged as to suit the laterals and the quantity of effluent to be dealt with. The collecting drains and laterals are butted together with open joints to receive the subsoil drainage.

Spacing.—The distance between the laterals will vary from 20 to 40 feet according to the nature of the soil, the closer spacing being used where there is stiff subsoil and shallow surfacte soil. In strong loam the specing may be 30 feet and in light soils 40 feet, With

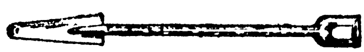
laterals so spaced the intervening ground should be effectively drained, the level of the water in the ground being somewhat as indicated in the following figure :—

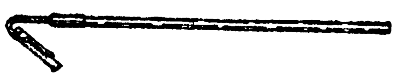


Enlarged section across two Laterals

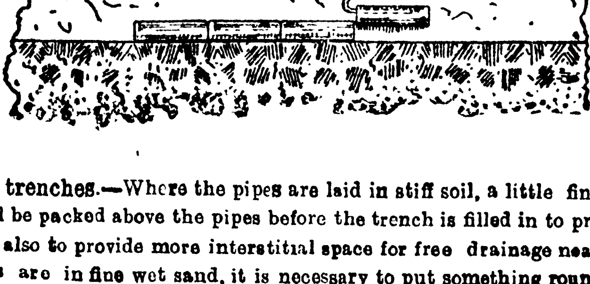
Laying drains.—The laying of main drains is carried out in the same way as that of sewage drains. Lines and levels should be carefully preserved as in sewage drains, though less care in jointing may be permitted.

The trenches for the collecting drains and the laterals are usually excavated with specially shaped long, narrow spades which enable a minimum of earth to be removed and the bottom of the trench is deepened and graded as required by the use of a peculiarly shaped hoe See sketches below. By means of these implements very narrow trenches can be made, from 1 foot to 18 inches wide at top, if the ground is not of a very loose nature. The proper alignment and gradients are maintained in the usual way by sight rails and boning rods.





When the trenches are ready, the pipes to be used are placed in sufficient numbers alongside the trench and they are hooked up, one by one, by a special tool and laid as shown in the following sketch :—

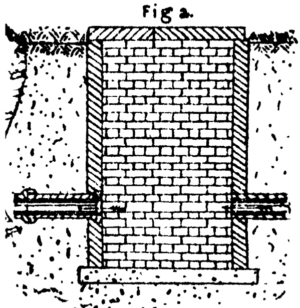


Filling trenches.—Where the pipes are laid in stiff soil, a little fine gravel or stone chips should be packed above the pipes before the trench is filled in to prevent their being shifted and also to provide more interstitial space for free drainage near the pipe joints. If the pipes are in fine wet sand, it is necessary to put something round them to keep out the sand which would otherwise run in with the water and choke the pipes in course

of time, in such positions the pipes are usually covered with earth or loam which will let the water through but keep out the sand.

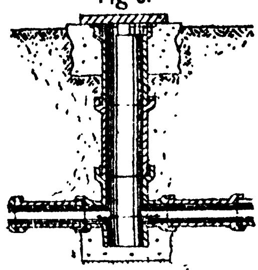
Manholes and silt pits. – Manholes should be built at all important junctions and 200 feet apart on all mains formed of glazed socket pipes with cement joints. Each manhole should also be a silt pit to intercept, as far as possible, any silt which may find its way into the pipes. There should also be a silt pit at every point where a reduction of gradient takes place, whether there is a manhole at that point or not to catch any deposit that may occur when the velocity is reduced. Large stoneware pipes are sometimes set vertically to take the place of regular manholes.

Fig a.



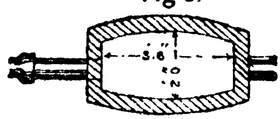
SECTION.

Fig c.



SECTION.

Fig b.



PLAN.

See Figs. a, b, c.

All manholes, pipe wells and silt pits need not be brought up to ground surface. Those that are buried should be covered by flag stones at a sufficient depth below surface to protect them from injury by ploughs and their position should be so marked on the drainage plans that there may be no difficulty in finding them when it is necessary to clean them.

Ventilation.—Ventilators are especially desirable for the subsoil drains of sewage farms as their efficiency depends to a great extent on the proper aeration of the soil. The open end of the outfall and the several manholes on the system afford facilities for the admission of air to the drains and suitable outlets can be provided by joining the heads of the laterals and carrying up pipe shafts from the connecting pipes above the ground surface in positions where they are not likely to be damaged.

Outlets.—Natural outfalls into streams, rivers or the sea are best if they can be obtained. The outlets should be at carefully selected places and they should be as few as possible consistent with a proper allotment of the lengths of the mains. An average of about 14 acres to each outlet appears to be the usual practice. The outlets should be iron pipes set in a brick or masonry face wall and they should be protected by a flap if they are likely to be submerged occasionally. They should be fixed a few inches above the ordinary high water level of the water-course they discharge into.